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University of Tennessee Agricultural Experiment Station

Andrew M. Soule

Phares O. Vanatter

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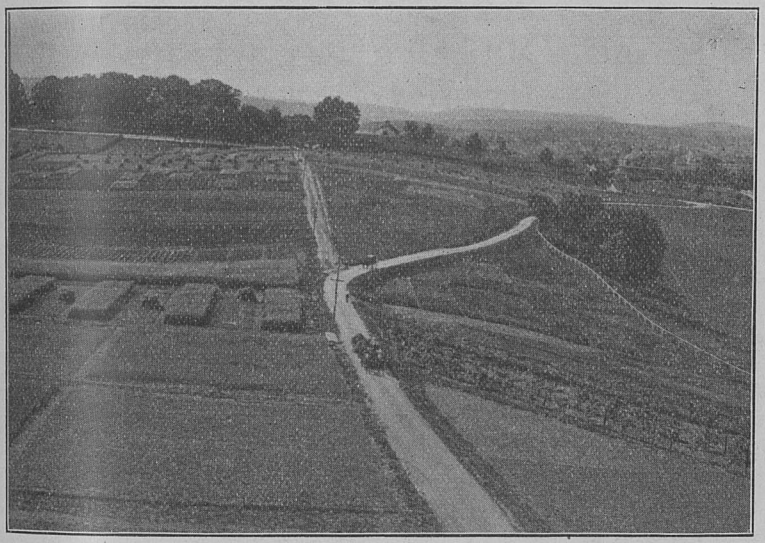

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INFLUENCE OF CLIMATE AND SOIL ON THE COMPOSITION AND MILLING QUALITIES OF WINTER WHEAT

BY

ANDREW M. SOULE AND PHARES O. VANATTER

A cooperative experiment between the Tennessee Experiment Station and the Bureau of Plant Industry, U. S. Department of Agriculture

KNOXVILLE, TENNESSEE

THE AGRICULTURAL EXPERIMENT STATION

OF THE UNIVERSITY OF TENNESSEE

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INFLUENCE OF CLIMATE AND SOIL ON THE COMPOSITION AND MILLING QUALITIES OF WINTER WHEAT

INTRODUCTION

Experiments looking to the improvement of winter wheat were commenced four years ago at the Tennessee Experiment Station, and so far two bulletins have been issued on the work. The present report is more comprehensive in every respect and deals with several new phases of the problem. The results which are now presented are of far-reaching importance to every one interested in Southern agricultural practice. The work was undertaken with a view to determining if possible what varieties of wheat are best adapted for cultivation in Tennessee, the relative merits of these varieties for flour and bread making as compared with wheats grown in other parts of the country, the possibility of improving varieties through selection and plant breeding, and finally the introduction and dissemination of varieties that might be of greater value than those generally cultivated.

LIMITED NUMBER OF GOOD VARIETIES

Of the 48 varieties of wheat which have been tested for several years not more than half a dozen can be called first-class. So far as yield is concerned Poole now ranks first, though it is not so hard a wheat as Fulcaster and not so good a milling wheat. Alongside of these comes Mediterranean, Niger and Kansas Mortgage Lifter. Fultz has done fairly well, but would not be classed as a leader. Harvest King is also a very good wheat, though it has not yielded quite so well as some of the other varieties. The varieties from Gold Coin No. 24 down to and including Early Pearl No. 40 are not satisfactory and can not be recommended for cultivation in Tennessee. Some of these varieties are regarded as among the best in other sections of the country, and this but illustrates the great influence that soil and climate have on the yield and composition of wheat, making evident the importance of Southern farmers' producing their own seed.

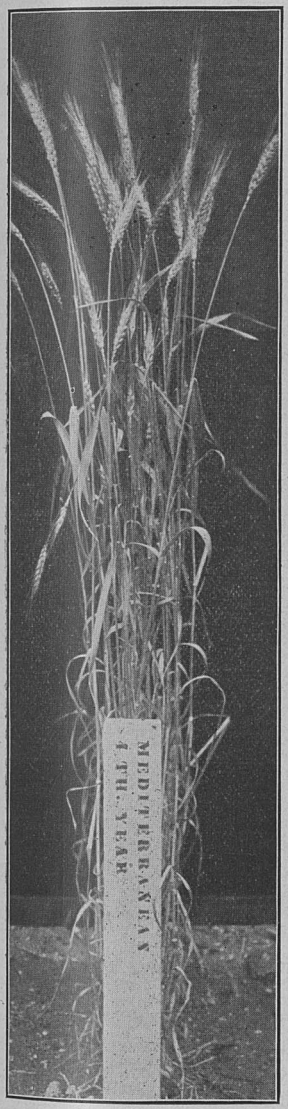
TABLE I—*Varieties of winter wheat*

Plat No.	Name of variety	No. of years grown	Source of seed	Date of ripening—June, 1903	Kind of head	Color of— chaff	Color of— grain	Yield of grain per acre 1900 bu.	Yield of grain per acre 1901 bu	Yield of grain per acre 1902 bu.	Yield per acre, 1903 Grain bu.	Yield per acre, 1903 Straw tons	Average yield per acre for four years—bu.	Avg. No. of grains per ounce for 1902-1903 as sown	Average No. of grains per head and ounce as grown, 1903 Head	Average No. of grains per head and ounce as grown, 1903 Ounce	Weight per measured bu. of grain, 1903—lbs.	Avg. weight per meas. bu. of grain for four years—lbs.
1	Poole	4	Ohio	10	Ba	R	R	40.20	31.83	28.33	48.54	3.77	37.23	776	19.58	965	58	58.56
2	Improved Poole	4	Ohio	10	Ba	R	R	38.95	33.00	29.30	47.60	3.42	37.21	759	21.09	888	57	58.56
3	Niger	4	Ohio	11	Be	W	R	40.62	29.80	32.38	44.27	3.09	36.77	619	19.01	786	57	59.00
4	Imp. Fulcaster	4	Ohio	11	Be	W	R	41.25	31.66	28.11	45.21	3.69	36.56	764	20.00	914	58	59.00
5	Fulcaster	4	Tenn	11	Be	W	R	41.66	32.50	31.59	39.27	3.06	36.25	693	19.02	772	59	59.76
6	Mediterranean	4	Tenn	11	Be	W	R	36.45	33.66	32.04	42.55	3.18	36.18	715	19.33	821	58	59.91
7	Kan. M. Lifter	4	Ky.	11	Be	W	R	33.54	36.66	33.36	39.74	2.86	35.82	675	21.33	800	58	58.81
8	Deitz Amber	4	Tenn	12	Be	W	R	38.95	30.66	26.21	40.21	3.54	34.01	709	17.53	841	60	60.01
9	Fultz	4	Ohio	10	Ba	W	R	40.20	27.60	24.58	43.65	2.82	34.01	844	24.70	941	59	59.50
10	Red May	4	Va.	9	Ba	R	R	23.75	32.33	37.84	41.66	2.90	33.89	878	19.07	1017	59	59.40
11	Red Russian	4	Ohio	11	Ba	R	R	33.75	30.33	24.06	47.29	2.96	33.86	807	23.05	914	59	58.75
12	Egyptian	4	Ohio	15	Be	W	R	37.70	30.83	25.48	39.79	2.96	33.45	826	20.82	989	58	59.80
13	Harvest King	4	Tenn	10	Ba	W	R	39.79	27.33	20.96	45.63	3.18	33.43	923	21.75	1044	60	59.80
14	Currell's Prolific	4	Tenn	9	Ba	R	W	37.50	25.16	28.36	40.31	2.37	32.83	911	23.65	1051	59	59.10
15	Forty Fold	4	N. Y.	16	Ba	R	R	25.20	23.50	29.30	52.29	3.73	32.57	759	24.89	859	56	57.75
16	Red Prolific	4	Tenn	10	Ba	R	R	37.50	30.33	28.33	33.13	3.16	32.32	904	19.23	971	57	58.57
17	Perfection	4	Ohio	13	Be	R	R	39.16	28.16	16.28	45.00	3.00	32.15	773	20.39	858	57	57.60
18	Rural N-Y'r No. 6	4	N. Y.	16	Ba	R	R	32.29	32.50	30.00	32.29	2.06	31.77	716	22.22	860	55	54.60
19	W. Golden Cross	4	Ohio	13	Be	R	W	38.54	28.16	20.24	39.06	2.63	31.50	786	24.77	849	57	57.50
20	Blue Ridge	4	N. C.	13	Ba	R	R	25.41	40.00	24.06	36.46	2.83	31.48	812	26.36	878	56	57.75
21	Velvet Chaff	4	Ohio	13	Ba	R	R	28.33	20.33	32.36	43.54	3.12	31.14	831	15.58	850	59	58.50
22	Early Ripe	4	Ohio	15	Ba	R	R	23.75	35.50	24.03	40.31	3.04	30.89	796	20.33	856	57	58.40
23	Mealey	4	Ohio	13	Ba	W	R	26.25	30.83	28.33	37.50	3.20	30.73	1016	34.86	1356	54	56.50
24	Gold Coin	4	Ohio	15	Ba	R	W	30.00	31.33	26.21	34.37	2.22	30.48	770	21.52	813	57	57.94
25	E. Red Clawson	4	N. Y.	15	Ba	R	R	32.91	20.00	31.66	37.29	2.48	30.46	666	16.34	694	55	56.25
26	Blue Straw Fultz	4	Tenn	10	Be	W	R	31.66	30.00	23.11	35.63	3.16	30.10	796	15.73	993	59	59.40
27	Beardless Fulk.	4	Va.	9	Ba	W	R	25.83	31.33	22.01	40.73	2.88	29.97	853	22.22	1088	59	58.12
28	B. W's Hybrid	4	Va.	10	Ba	R	R	13.85	28.16	37.63	38.33	2.48	29.49	804	20.00	960	57	58.00
29	Amer. Bronze	4	Ohio	13	Ba	W	R	26.87	26.83	35.96	27.29	1.66	29.24	759	29.35	897	59	59.00
30	Democrat	4	Ohio	13	Be	W	W	18.33	26.33	31.91	39.16	2.78	28.93	832	18.75	918	57	58.60
31	Early Gen. G'nt	4	Ohio	13	Be	R	W	41.45	18.33	20.24	34.89	2.20	28.73	822	22.37	925	57	57.12
32	Valley	4	Tenn	13	Be	W	R	13.75	25.00	35.00	39.58	2.74	28.33	799	21.87	1000	59	58.12
33	New Monarch	4	Ohio	11	Ba	W	R	16.25	27.00	34.78	31.66	2.30	27.42	781	24.69	971	57	57.70
34	White W. No. 6	4	N. Y.	13	Ba	R	W	29.37	27.50	19.30	30.73	1.68	26.72	787	19.71	788	56	57.50
35	Dawson's G. Ch.	4	Ohio	13	Ba	R	W	20.83	36.33	16.16	33.33	1.80	26.66	830	23.46	859	56	57.50
36	Winter King	4	Tenn	15	Ba	R	W	29.58	18.33	24.78	33.44	2.32	26.53	793	22.12	892	57	57.00
37	Rice Wheat	4	Ky.	9	Ba	W	R	19.37	26.50	28.57	27.50	2.43	25.48	799	16.90	933	60	57.62
38	New Columbia	4	Ohio	9	Ba	W	R	20.60	19.16	22.15	35.31	2.19	24.30	854	22.92	887	57	57.00
39	Eclipse	4	Tenn	13	Be	R	R	17.08	16.66	27.15	36 25	2.01	24.28	657	18.17	785	57	58.12
40	Early Pearl	4	Tenn	8	Ba	W	R	29.16	18.00	21.68	27.60	2.49	24.11	803	16.77	969	59	57.90
41	Red Cross	3	Wis.	13	Be	W	R	.....	21.66	41.91	38.33	2.10	33.97	589	17.19	737	57	58.10
42	California Red	3	Tenn	10	Ba	R	R	.....	24.00	32.15	43.33	2.80	33.16	771	19.15	998	58	58.10
43	Hopper	3	Tenn	12	Be	W	R	.....	25.66	35.24	36.88	3.04	32.59	719	17.52	832	59	58.70
44	Diamond Grit	3	Ont.	15	Ba	W	R	.....	20.33	29.54	38.44	2.59	29.44	885	21.34	984	61	59.60
45	Turkey Red	3	Iowa	15	Be	W	R	.....	17.66	29.30	38.85	2.48	28.60	952	15.83	1190	60	57.60
46	Lancaster	2	Va.	15	Be	R	R	.....	.....	26.91	38.33	2.33	32.62	661	16.10	831	57	58.50
47	No. 4281	2	U.S.	13	Be	R	W	.....	.....	25.00	36.15	2.62	30.58	760	25.07	853	57	58.00
48	No. 5342	2	D.A.	9	Be	R	R	.....	.....	21.66	33.33	1.93	27.50	1068	19.21	1336	59	58.75

SOME LEADING VARIETIES

Among the leading varieties Poole made a satisfactory yield every year, producing as high as 48.5 bushels in 1903; the average for four years being 37.23 bushels. Niger, which stands third on the list for 1903, made a yield of 44.27 bushels and an average for four years of 36.77 bushels. Fulcaster, which stands fifth, made a yield of 39.27 bushels and an average

for four years of 36.25 bushels. Mediterranean made a better yield in 1903 than Fulcaster—42.55 bushels—and an average for four years of 36.18 bushels. These varieties have made a very satisfactory record, and as they produce a plump berry and are among the hardiest and best milling wheats grown they are worthy of public favor. The most serious drawback

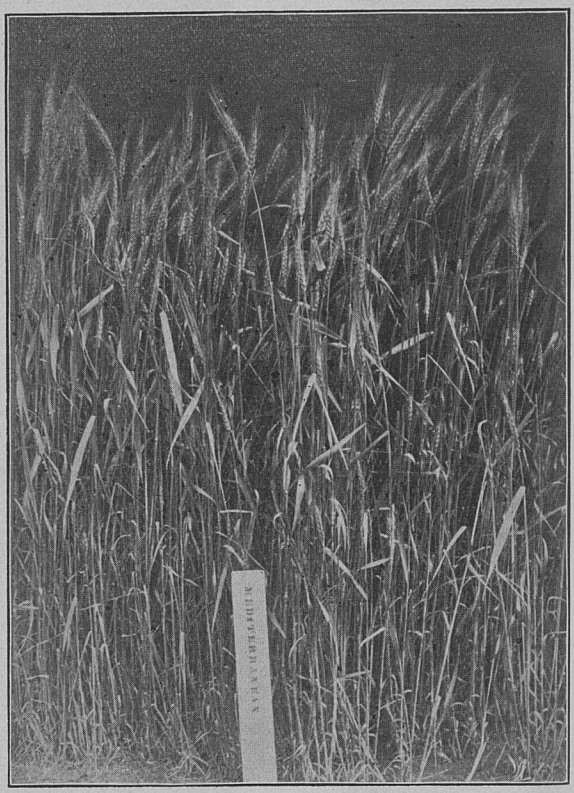


On the Left Mediterranean Grown Four Years on Station Grounds
Notice that the sample bought to compare with it is not Mediterranean

to their cultivation is the difficulty of securing pure seed, true to name. The Station hopes to obviate this trouble in the course of time by growing considerable quantities of these seeds to distribute to leading farmers throughout the State, who will be expected to grow them and re-distribute to their neighbors at a reasonable price.

YIELD OF STRAW

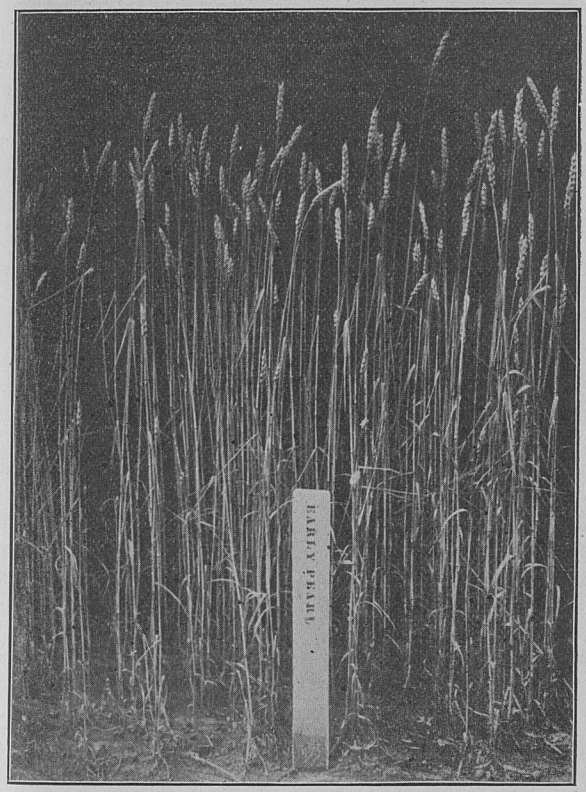
The straw produced by the different varieties varied somewhat according to the yield, though as a rule it is influenced more by the natural



MEDITERRANEAN, A LEADING VARIETY, SHOWING DENSE NATURE OF GROWTH

fertility of the soil, the fertilizers used, and the climate. The yield of straw obtained the present year was very heavy with most varieties, Poole, Fultz and Mediterranean each making more than three tons per acre. The small yield of such varieties as American Bronze and Dawson's Golden Chaff is due to the fact that they are not well adapted to Tennessee. In 1902 the yield of straw was very small, considering the grain yield. In that year Kansas Mortgage Lifter yielded 33.36 bushels of grain and 1.67

ton of straw; Red Cross, 41.91 bushels of grain and 1.79 ton of straw; and Mealey, 28.33 bushels of grain and .60 ton of straw. The small yield of grain in 1902 was due to the severity of the winter, which destroyed much of the wheat, the yield of grain obtained being due to the remarkable stooling qualities exhibited by all the varieties. Turkey Red, Egyptian and one or two other varieties which are naturally weak in the straw are inclined to fall down. All the other varieties produce plenty of straw of good quality in proportion to the yield.



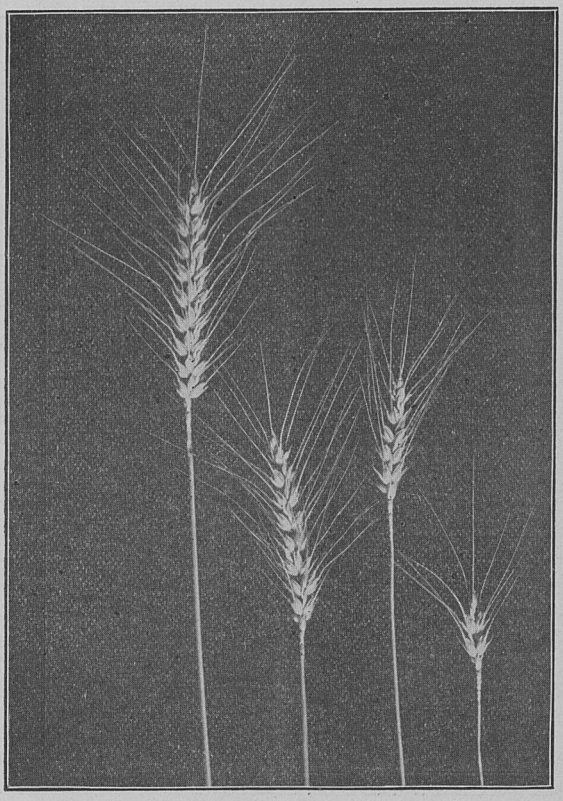
EARLY PEARL, A POOR VARIETY, DOES NOT STOOL SO VIGOROUSLY AS MEDITERRANEAN

GRAINS PER HEAD AND OUNCE

The average number of grains per ounce as sown in 1902 and 1903 has been made a matter of record. The smallest number of grains per ounce was shown by Red Cross, 589; followed by Eclipse, 657, and Lancaster, 661. Fulcaster had 693 grains per ounce and Niger 619; Mediterranean and Poole, 715 and 776, respectively. The largest number of grains

per ounce, 1068, was shown by No. 5342, a foreign variety furnished by the U. S. Department of Agriculture. Mealey was a close second, with 1016 grains. The variation in the number of grains per ounce is surprising and indicates a wide variation in size and general character. It is evident that by the selection of a definite type of berry larger yields might be obtained as well as a more nearly uniform product when milled.

The smallest number of grains per head was 15.58, from Velvet Chaff; from Blue Straw Fultz the yield was 15.73, and from Turkey Red 15.83.

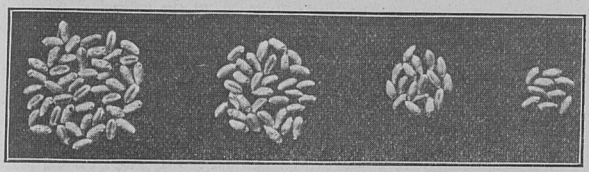


TYPE HEADS OF FULCASTER, SHOWING IMPORTANCE OF STANDARDIZING

Mealey had the largest number, 34.86, American Bronze being second with 29.35, and Blue Ridge third with 26.36. While these varieties have large heads they do not possess any special merit for Tennessee. The leading varieties, such as Fulcaster, Poole and Mediterranean, all contained an average of about 19 grains per head. It is evident that the size of the head does not measure the productive capacity. A medium-sized head that fills well with plump, heavy berries leads in nearly every instance. By paying

attention to these details one becomes familiar with the qualities of the several varieties and is able to determine the points to be considered in an endeavor to improve them. Since it has been demonstrated that varieties can best be bred and developed at home the matter is of grave concern to Tennessee farmers.

The number of grains per ounce grown varied considerably from the number sown in the original plats. No doubt the number and size of grains will vary from year to year, owing somewhat to varietal characters and to soil and climatic conditions. One year the grains may be much plumper and heavier than another. The variation between the number of grains per ounce sown and the number grown is much greater with some varieties than others, depending largely on their adaptability to local conditions. Ordinarily a bushel and a half of seed has been found to be the right amount to sow. In a very favorable season a less amount would probably give equally good results. In a severe winter two bushels of seed would be better. Mealey contains 1016 berries per ounce and Early Red Clawson 666. If these two varieties were sown in equal quantities many more seeds of Mealey would be sown on the acre, and the plants might



GRAINS FROM TYPE HEADS OF FULCASTER SHOWN ON OPPOSITE PAGE

be very much crowded. As is well known, when plants are much crowded they do not give best results, for crowding prevents free stooling and might often account for the difference in yields obtained. The matter is of more importance than one would suspect at first, and in the future when varieties are to be compared the same number of grains will be seeded on all the plats.

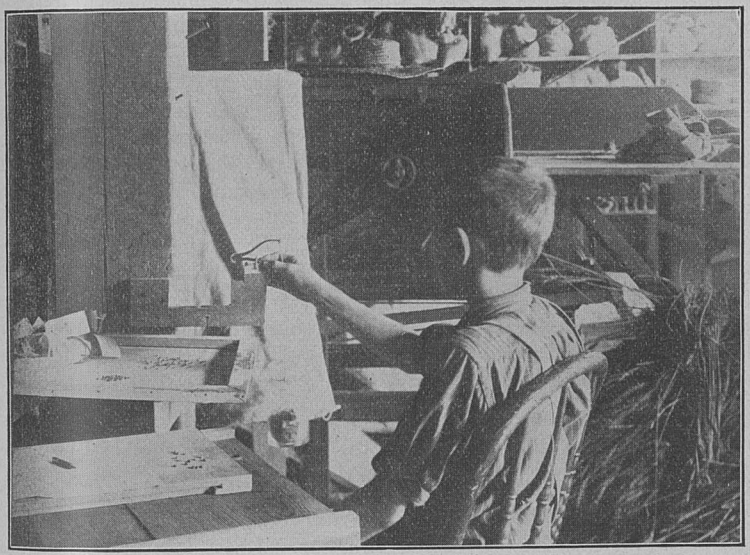
STANDARDIZING VARIETIES OF WHEAT

It is very important to standardize varieties for experimental work, in order that conclusions may be fairly drawn and the best results obtained from cross-fertilizing for the sake of improving varieties. The difficulty was early recognized and the work was commenced with two objects in view: first, to obtain pure seed so as to make the comparisons of varieties reliable; and second, to standardize the varieties and note their qualities definitely so that when it becomes desirable, as it soon will, to cross these for the sake of improving wheats for the South, we shall know exactly what we are working with. Has there not been a mistake made in many instances in crossing wheats before the characters were well established and thus getting results not truly representative of the varieties? Besides the importance of standardizing the variety for cross-fertilizing, is it not a matter of grave importance to have it pure, so that it may be tested

TABLE II—*Relative hardness of grains of varieties of winter wheat*

Number	Name of variety	1901				1902				1903				Average number unbroken grains in three years			
		Number unbroken in 100 grains			Total number unbroken in 300 grains	Number unbroken in 100 grains			Total number unbroken in 300 grains	Number unbroken in 100 grains			Total number unbroken in 300 grains				
		Weight, 1.5 lb.	Weight, 1.75 lb.	Weight, 2 lbs.		Weight, 1.5 lb.	Weight, 1.75 lb.	Weight, 2 lbs.		Weight, 1.5 lb.	Weight, 1.75 lb.	Weight, 2 lbs.		Weight, 1.5 lb.	Weight, 1.75 lb.	Weight, 2 lbs.	Total number unbroken grains in three years
1	Mealey	73	55	19	147	82	62	15	159	80	41	18	139	78	53	17	148
2	Fulcaster	69	52	20	141	76	42	15	133	82	53	6	141	76	49	13	138
3	Kansas Mortgage Lifter	68	60	18	146	70	38	7	115	79	37	19	135	72	45	15	132
4	Niger	64	38	10	112	73	48	10	131	70	39	30	139	69	42	16	127
5	Deitz Amber	67	46	8	121	69	26	3	98	85	57	21	163	74	43	10	127
6	Mediterranean	68	50	19	137	71	37	8	116	77	34	8	119	72	40	22	124
7	Turkey Red	54	37	18	109	67	40	5	112	76	17	12	105	66	31	12	109
8	New Monarch	43	16	7	66	87	49	17	153	60	36	13	109	63	34	12	109
9	Improved Fulcaster	69	51	16	136	61	24	5	90	51	32	8	91	60	36	10	106
10	Hopper	58	36	20	114	61	14	8	83	69	45	3	117	63	32	10	105
11	Early Pearl	52	35	9	96	50	17	..	67	64	45	12	121	55	33	7	95
12	Eclipse	60	37	7	104	67	24	2	93	68	14	2	84	65	25	4	94
13	Diamond Grit	23	11	8	42	57	26	4	87	83	39	14	136	54	25	9	88
14	Rice Wheat	61	30	16	107	60	14	1	75	42	26	10	78	55	23	9	87
15	White Golden Cross	61	40	10	111	44	17	2	63	48	26	11	85	51	27	8	86
16	Early Genessee Giant	65	43	11	119	41	9	..	50	47	24	11	82	51	26	7	84
17	Early Ripe	71	37	12	120	38	7	..	45	43	31	8	82	51	25	6	82
18	Rural New-Yorker No. 6	45	26	2	73	49	29	2	80	58	19	6	83	51	25	3	79
19	Early Red Clawson	42	17	3	62	72	19	1	92	47	20	7	74	54	19	3	76
20	Valley	40	9	2	51	41	24	1	66	70	32	10	112	50	22	4	76
21	New Columbia	26	25	7	58	67	30	2	99	34	21	5	60	42	25	5	72
22	Blue Straw Fultz	48	27	7	82	46	13	..	59	59	13	4	76	51	17	4	72
23	Poole	48	26	8	82	51	7	..	58	46	20	9	75	48	18	6	72
24	Improved Poole	42	16	6	64	36	8	..	44	62	29	13	104	47	18	6	71
25	Beech Wood's Hybrid	37	18	11	66	54	25	3	82	49	8	4	61	47	17	6	70
26	Red Cross	42	27	9	78	51	17	..	68	31	22	8	61	41	22	6	69
27	Egyptian	55	30	4	89	44	7	1	52	35	13	5	53	45	17	3	65
28	Fultz	60	18	4	82	27	10	1	38	42	20	6	68	43	16	4	63
29	Velvet Chaff	24	5	..	29	35	8	..	43	63	39	14	116	41	17	5	63
30	Winter King	30	9	1	40	35	12	1	48	62	29	3	94	42	16	2	60
31	California Red	31	13	5	49	36	4	..	40	50	31	6	87	39	16	4	59
32	Gold Coin	28	15	1	44	21	2	1	24	66	29	11	106	38	15	5	58
33	Harvest King	48	20	1	69	23	10	1	34	40	16	4	60	37	14	2	53
34	Forty Fold	23	21	4	48	39	6	..	45	40	19	4	63	34	15	3	52
35	Red Russian	29	18	5	52	10	4	1	15	60	20	7	87	33	14	4	51
36	Perfection	43	15	2	60	22	3	..	25	39	21	3	63	35	13	1	49
37	Dawson's Golden Chaff	38	22	2	62	31	6	..	37	28	8	8	44	33	12	3	48
38	Red May	24	14	4	42	36	14	..	50	25	14	2	41	28	14	2	44
39	Blue Ridge	44	21	2	67	22	2	..	24	20	10	4	34	29	11	2	42
40	White Wheat No. 6	26	13	..	39	43	8	3	54	45	8	3	56	38	9	2	39
41	Beardless Fulcaster	22	7	..	29	17	5	1	23	47	12	7	66	28	8	3	39
42	Red Prolific	30	15	..	45	28	13	..	41	21	9	0	30	26	13	0	38
43	American Bronze	25	19	2	46	20	3	..	23	24	11	1	36	23	11	1	35
44	Currell's Prolific	35	19	4	58	15	3	..	18	16	7	2	25	22	10	2	34
45	Democrat	20	9	1	30	18	1	..	19	24	3	0	27	21	4	0	25
46	No. 4281	..	..	..	..	..	..	..	..	77	25	10	112	..	..	..	....
47	Lancaster	..	..	..	..	..	..	..	..	77	24	5	106	..	..	..	....
48	No. 5342	..	..	..	..	..	..	..	..	29	21	0	50	..	..	..	....

through a series of years and its relative value determined? Is it not possible through the standardizing and careful selection of a variety to improve its quality very materially? And will it not be interesting to compare the standardized varieties with the crossbreeds which may be obtained from them in later years? The authors believe this to be a matter of much greater moment than at first seems reasonable to assume. There is sometimes a tendency to try every new variety for a year or two and then rush into cross-fertilization extensively before determining what is best to work with. As a result hundreds of crossbreeds are unsatisfactory and less valuable than well established varieties, which may be improved through standardizing.



Apparatus for Testing the Relative Hardness of Wheat Grains

WEIGHT PER MEASURED BUSHEL

In the last column of the table will be found the weight per measured bushel for 1903 and the average for four years. From the figures presented one would suppose that the wheats grown were light, but such was not the case, for they were not graded before the weights per measured bushel were taken.

TESTING THE HARDNESS OF GRAIN

For three years past a record has been kept of the hardness of the grain of the individual varieties. The method has given only relative results; but every care has been taken to have the conditions as nearly uniform as possible, and the tests seem to be fair. That the method is at least fairly reliable is shown by the fact that the leading varieties have

occupied the same relative places for several years. It is too early to say what the value of this test will be, but the hardest varieties are generally believed to produce the best milling wheats.

The best yielding varieties are not necessarily the hardest. Mealey, which is twenty-third in yield, is first in hardness; Fulcaster, fifth in yield, is second in hardness; and Poole, first in yield, is twenty-third in hardness. On the average for three years 148 grains of Mealey remained unbroken; 138 of Fulcaster, and 132 of Kansas Mortgage Lifter. Niger and Deitz Amber, both hard varieties, had each 127 grains unbroken; Mediterranean had 124. After that the number unbroken fell off very rapidly. Poole had 72 and Democrat the smallest number, 25. It is evident that a large number of the varieties are very soft. Among the number which are generally cultivated are Fultz, with 63, and Currell's Prolific, with 34. The relative number broken by the different weights for the three years was very nearly uniform. The tests were made with three different weights—1.50, 1.75 and 2 pounds, respectively. The weight was attached to the upper arm of the pinchers by means of a wire. The operator opened the arms of the pinchers just wide enough to take the grain and allowed the weight to settle gently. The grains remaining unbroken were set aside and counted. Of each variety 300 grains were counted out (100 for testing with each weight) and put into separate bags. The grains were kept under as nearly uniform conditions as possible, and the tests were made as far as practicable when the weather was hot and dry, since the grains would of course absorb moisture in rainy weather and become much softer. If it be true that the hardness of grain is a measure of the value of wheat for flour and bread making, then the test is extremely valuable.

THE RELATIVE PROTEIN CONTENTS OF VARIETIES OF WHEAT

Table III gives the yield and the nitrogen and protein contents of each variety grown on the Station farm for the past four years. On the average for four years Mediterranean stands first in protein content, with 17.39 per cent, and Fulcaster third, with 17.06 per cent. Poole is seventeenth, with 15.43 per cent, and Niger twenty-second, with 15.20 per cent. Mealey, which had the hardest grain of all the varieties, stands sixteenth, with 15.64 per cent of protein. All the varieties grown for four years have a high protein content, the lowest one of all being Dawson's Golden Chaff, with 13.19 per cent.

Some varieties that have made poor yields and can not be regarded as of any value for culture in Tennessee have a remarkably high protein content for one or more years. In 1900 Rice wheat contained 21.12 per cent of protein, the average for four years being 17.28. Blue Straw Fultz, Beech Wood's Hybrid, Valley, and Rural New-Yorker No. 6 all had between 16 and 17 per cent of protein. Some of these varieties are regarded as poor for milling purposes and low in protein in sections of the country where they are quite extensively grown, and these facts lead to the conclusion that climatic and soil conditions have a decided influence on the protein content.

TABLE III—*The protein contents of varieties of winter wheat*

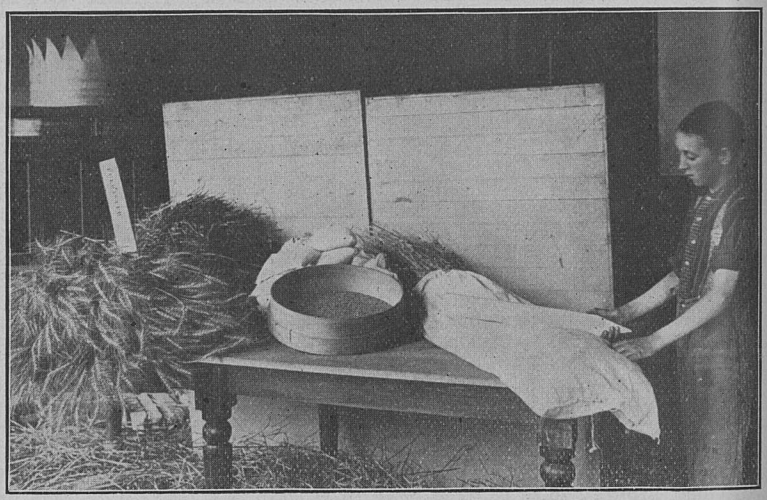
Number	Name of variety	1900		1901		1902		1903		Average yield of grain—bu.	Average yield protein for four years—per cent
		Yield—bu.	Protein—per cent	Yield—bu.	Protein—per cent	Yield—bu.	Protein—per cent	Yield—bu.	Protein—per cent		
1	Mediterranean.	36.45	17.50	33.66	16.21	32.04	19.38	42.55	16.47	36.18	17.39
2	Rice Wheat ...	19.37	21.12	31.33	14.75	28.57	17.92	27.50	15.33	25.48	17.28
3	Fulcaster	41.66	18.45	32.00	15.60	31.59	18.27	39.27	15.92	36.25	17.06
4	Deitz Amber ..	38.95	17.50	30.66	15.28	26.21	19.56	40.21	15.18	34.01	16.88
5	Kan. M. Lifter.	33.54	17.50	36.66	15.80	33.36	18.51	39.74	15.44	35.82	16.81
6	Blue St'w Fultz	31.66	17.56	30.00	15.06	23.11	17.56	35.63	16.56	30.10	16.69
7	B. W.'s Hybrid	13.85	21.92	27.00	13.77	37.63	15.74	38.33	15.00	29.49	16.61
8	Valley	13.75	20.64	28.16	14.35	35.00	15.27	39.58	14.59	28.33	16.21
9	R. N.-Y'r. No.6	32.29	17.08	20.33	16.27	30.00	18.26	32.29	12.48	31.77	16.02
10	Imp. Fulcaster.	41.25	17.49	31.66	14.27	28.11	18.31	45.21	13.96	36.56	16.01
11	Velvet Chaff ..	28.33	16.08	23.50	15.58	32.63	17.44	43.54	14.74	31.14	15.96
12	White G. Cross	38.54	17.67	28.16	15.16	20.24	17.40	39.06	13.22	31.50	15.86
13	Democrat	18.33	15.40	25.00	15.92	31.91	16.47	39.16	15.44	28.93	15.81
14	Harvest King..	39.79	15.80	27.33	13.83	20.96	17.99	45.63	15.17	33.43	15.70
15	Red Russian ..	33.75	17.39	30.33	15.30	24.06	16.81	47.29	13.27	33.86	15.69
16	Mealey	26.25	16.89	30.83	14.02	28.33	16.83	37.50	14.82	30.73	15.64
17	Poole	40.20	16.05	31.83	14.31	28.33	18.48	48.54	12.89	37.23	15.43
18	Currell's Prolif.	37.50	15.71	25.16	15.88	28.36	16.69	40.31	13.39	32.83	15.41
19	Fultz	40.20	17.67	27.60	13.94	24.58	17.32	43.65	12.60	34.01	15.38
20	B'less Fulcaster	25.83	14.57	31.33	15.47	22.01	17.07	40.73	14.18	29.97	15.32
21	Imp. Poole	38.95	16.65	33.00	14.09	29.30	17.13	47.60	13.01	37.21	15.22
22	Niger	40.62	16.38	29.80	13.38	32.38	16.68	44.27	14.35	36.77	15.20
23	Perfection	39.16	15.62	28.16	14.26	16.28	17.64	45.00	12.92	32.15	15.11
24	New Columbia.	20.62	17.30	27.50	14.30	22.15	15.61	35.31	13.10	24.30	15.08
25	Early Ripe....	23.75	15.04	35.50	14.32	24.03	17.83	40.31	12.67	30.89	14.97
26	Red May.....	23.75	15.49	32.33	14.58	37.84	16.35	41.66	13.41	33.89	14.96
27	Egyptian	37.70	15.69	30.83	13.94	25.48	17.59	39.79	12.50	33.45	14.93
28	Eclipse	17.08	15.02	26.33	14.89	27.15	15.99	36.25	13.68	24.28	14.90
29	Winter King ..	29.58	15.50	19.66	14.93	24.78	15.33	33.44	13.01	26.53	14.69
30	E. R. Clawson.	32.91	15.41	20.00	14.23	31.66	16.05	37.29	12.76	30.46	14.61
31	Amer. Bronze .	26.87	15.92	26.83	13.18	35.96	16.36	27.29	12.91	29.24	14.59
32	White W. No. 6	29.37	14.62	18.00	16.15	19.30	14.18	30.73	12.79	26.72	14.44
33	Forty Fold....	25.20	15.49	26.50	14.08	29.30	15.82	52.29	12.17	32.57	14.39
34	New Monarch.	16.25	13.62	21.66	14.13	34.78	15.69	31.66	13.62	27.42	14.27
35	Dawson's G. C.	20.83	12.95	36.33	12.75	16.16	15.07	33.33	11.97	26.66	13.19
36	Early Gen.G'nt.	.....	.....	18.33	16.29	20.24	18.04	34.89	14.65	28.73	16.33
37	Red Prolific...	37.50	16.16	.....	.....	28.33	18.46	33.13	13.94	32.32	16.19
38	Early Pearl ...	.....	.....	16.66	15.31	21.68	16.86	27.60	15.64	24.11	15.94
39	Blue Ridge....	25.41	15.05	.....	.....	24.06	17.13	36.46	12.87	31.48	15.02
40	Gold Coin.....	.....	.....	18.83	14.70	26.21	15.14	34.37	13.13	30.48	14.32
41	Hopper	.....	.....	25.66	17.43	35.24	17.83	36.88	16.38	32.59	17.21
42	California Red.	.....	.....	24.00	16.03	32.15	16.02	43.33	13.94	33.16	15.33
43	Diamond Grit .	.....	.....	20.33	15.59	29.54	16.30	38.44	14.06	9 44	15.32
44	Red Cross.....	.....	.....	35.00	14.85	41.91	15.54	38.33	13.64	33.97	14.68
45	Turkey Red...	.....	.....	17.66	15.21	29.30	14.60	38.85	12.52	28.60	14.11
46	No. 4281	.....	.....	.....	.....	25.00	16.63	36.15	14.63	30.58	15.63
47	Lancaster	.....	.....	.....	.....	26.91	17.08	38.33	13.75	32.62	15.42
48	No. 5342	.....	.....	.....	.....	21.66	15.92	33.33	13.63	27.50	14.78

The results set forth in the table are all the more remarkable since the climate of Tennessee has been regarded as unfavorable to the production of winter wheat. The general sentiment in this regard seems to be altogether faulty, as the present investigations indicate. The data pre-

sented are more valuable on that account, for they show beyond question that Tennessee is one of the finest wheat producing sections in the world. When this fact is fully recognized and wheat is grown as extensively as the natural conditions warrant, a new and profitable industry will be established. The value of this demonstration can not be estimated in dollars and cents, but it can be safely said that no more important results have ever been published by the Station.

All the analytical work in connection with the table was performed by Prof. Chas. A. Mooers, Chemist of the Tennessee Agricultural Experiment Station, to whom we desire to convey our thanks for the many courtesies received at his hand, as the labor involved was both exacting and arduous.

The table shows that the protein content in the different years was not uniform. It was highest in 1900 and 1902 and lowest in 1901 and



METHOD OF THRESHING 800 HEADS SELECTED FROM EACH VARIETY FOR THE PURPOSE OF STANDARDIZING

1903. In some instances the variation was marked. Fulcaster contained 18.45 per cent of protein in 1900, 15.60 per cent in 1901, 18.27 per cent in 1902, and 15.92 per cent in 1903. Beech Wood's Hybrid, a very poor variety of wheat, contained 21.92 per cent in 1900, 13.77 in 1901, 15.74 in 1902, and 15 in 1903. Can any satisfactory explanation be offered for this phenomenon? That is a question of more than passing importance, because it constitutes the key to the situation and may lead to an understanding of why so high a protein content is shown by wheat grown in Tennessee.

INFLUENCE OF CLIMATE ON PROTEIN CONTENT

The soil of the State is not remarkably rich but is certainly well adapted for wheat if rationally treated; and the soil probably has some influence on the yield and quality of the wheat obtained, but to what ex-

tent it is impossible to say. It is more than likely that the climate exerts a much greater influence, as the accompanying meteorological data seem to indicate.

The autumn of 1899 was a very good wheat season. The varieties were seeded about October 15 and went through the winter in very good condition. They were attacked by the Hessian fly but the injury was very slight. The rainfall was fairly well distributed through the autumn but was somewhat deficient during the winter and decidedly so in March, April and May. Wheat makes its principal growth in Tennessee in March and April; it flowers as a rule about May 12 to 15, and is generally ready to cut about June 9.

In the years 1900 and 1902 the weather conditions were very similar during the months of March, April, May and June. There was a deficiency in rainfall in March, April and May, 1900, it being most decided in April and May, though the temperature was not much above normal. The dryness gave the wheat a short, quick ripening period, which explains its high protein content, as will be shown later. During the last week or ten days of the ripening period in June, 1900, there was an excessive rainfall. The conditions in March, April, May and June, 1902, were very similar, giving another short, quick ripening period with a minimum supply of water in the soil, due to the deficiency in the rainfall. The temperatures were very nearly the same for the two years.

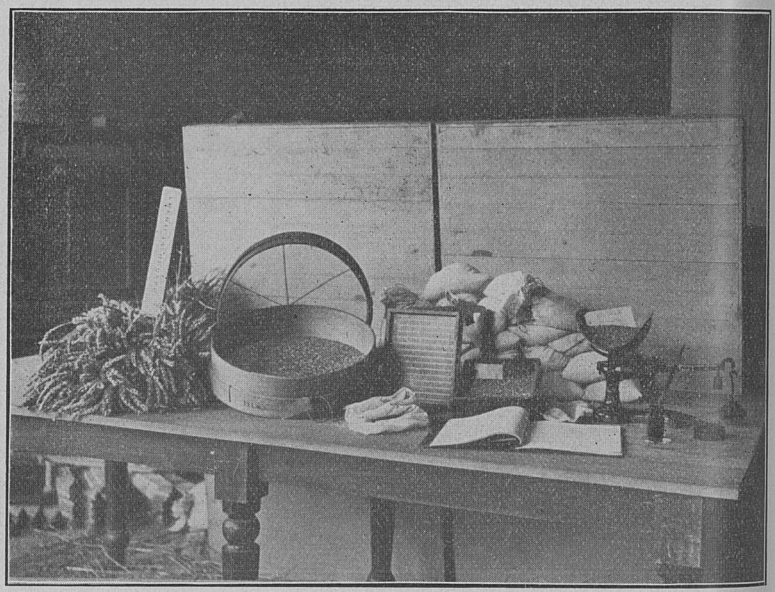
TABLE IV—*Average annual temperature and rainfall 1899-1903*

Number	Month	1899–1900				1900–1901				1901–1902				1902–1903			
		Temp.		Rainfall		Temp.		Rainfall		Temp.		Rainfall		Temp.		Rainfall	
		Mean	Departure from normal	Total inches	Departure from normal	Mean	Departure from normal	Total inches	Departure from normal	Mean	Departure from normal	Total inches	Departure from normal	Mean	Departure from normal	Total inches	Departure from normal
1	July	76.8	+ 74°	3.93	— .39	78.8	+3°	3.90	— .43	80.8	+5°	.69	—3.52	78.1	+ 2°	3.73	— .47
2	August	78.4	+ 22°	1.52	—2.55	80.2	+5°	3.64	— .30	75.2	....	10.48	+6.33	76.8	+ 2°	2.39	—1.70
3	September	70.0	+111°	1.68	—1.02	75.7	+7°	3.41	+ .61	68.1	—1°	4.13	+1.29	67.9	— 1°	8.04	+5.04
4	October	61.6	+ 19°	2.53	— .26	65.6	+8°	2.21	— .49	58.4	.....	1.57	—1.10	59.9	+ 2°	.99	—1.50
5	November	50.9	+123°	.89	—2.92	49.2	+3°	5.63	+1.94	42.8	—3°	1.30	—2.30	54.0	+ 10°	4.03	+ .42
6	December	37.8	— 65°	2.70	—1.41	41.7	+3°	2.75	—1.16	35.0	—4°	12.34	+8.16	39.6	+ 1°	3.46	— .70
7	January	38.3	slightly above	3.35	—1.97	39.0	+1°	4.31	— .98	36.9	—1°	3.71	—1.52	37.4	— 2°	2.10	—3.04
8	February	37.2	— 5°	5.52	+ .34	36.4	—5°	.79	—4.07	33.8	—7°	3.53	—1.29	42.0	+ 9°	8.35	+3.42
9	March	46.0	— 2°	3.64	— .96	47.6	.....	4.32	—1.21	48.8	+1°	6.37	+ .82	55.8	+ 8°	6.96	+1.39
10	April	59.1	+ 1°	1.92	—2.94	51.4	—7°	5.35	+ .59	55.9	—2°	1 79	—2.88	56.2	—1.3°	7.21	+2.47
11	May	67.8	+ 2°	1.72	—2.16	65.6	.....	4.03	+1.50	71.2	+5°	2.09	—1.74	69.0	+2.7°	3.09	— .72
12	June	74.6	+ 1°	6.42	+2.26	74.8	+1°	6.44	+2.21	74.9	+1°	5.45	+1.19	69.1	+4.4°	3.39	— .85

In the years 1901 and 1903 the conditions were reversed. There was a surplus rainfall in April, May and June, 1901, and a deficiency in March. In 1903 there was a surplus in March and April and a deficiency in May and June. The temperature during the ripening period of 1901 and 1903 was somewhat lower, and there was a better distribution of the rainfall and a larger amount of water in the soil, giving a cooler and a longer

ripening period for the wheat. It is also noteworthy that the largest yields of straw were in the years 1901 and 1903, an important fact as related to the influence of climate on the protein content of wheat.

According to investigations* made by P.-P. Dehérain and C. Dupont in France, a short ripening period with a hot, dry season produces a wheat containing a high protein and a low starch content. They compared the analyses of grains from the harvests of 1888 and 1889. In the year 1888 the ripening period was slow and resulted in the production of 12.60 per cent of gluten and 77.02 per cent of starch; whereas, in 1889, when the conditions were reversed, the summer being hot and dry and the ripening period short, the gluten content was 15.03 per cent and the starch 61.9.



Sieves and Scales Used in Cleaning Samples

As is well known, wheat has no reserve of carbohydrates, and the starch must be elaborated from new material. The question therefore is, Whence is the starch obtained? Wheat does not produce much starch during the vegetative period, and as it does not form carbohydrates from the carbonic acid of the air it must get them from some other source. These investigators concluded from an elaborate chemical analysis of the wheat plant in various stages of ripening that the carbohydrates are obtained from the upper portion of the stem, which performs the functions of the leaves in elaborating starch. Hence, in a slow ripening period, when the stem remains green for a considerable length of time, more starch is elaborated

*"Origin of Starch in Wheat Grain," P.-P. Dehérain and C. Dupont, *Ann. Agron.* 28, 1902, No. 10, pages 522-527.

and the gluten and protein accordingly fall short; and in a quick ripening period less starch is formed and the protein content rises. This explanation coincides exactly with the meteorological data presented above and with the conclusions reached independently at the Station.

The climate would therefore seem to have more to do with the high protein content of wheat grown in Tennessee than any other influence. And as the temperatures during the ripening period are uniformly high and the rainfall is not excessive, as is shown by the data for four years, the explanation given accounts satisfactorily for the high protein content obtained and indicates that the per cent of protein will be higher in years when the rainfall for these months is below the normal, thus establishing fully the value of the soil and climatic conditions of Tennessee for the production of wheat rich in protein.

INFLUENCE OF FERTILIZERS ON PROTEIN CONTENT OF WHEAT

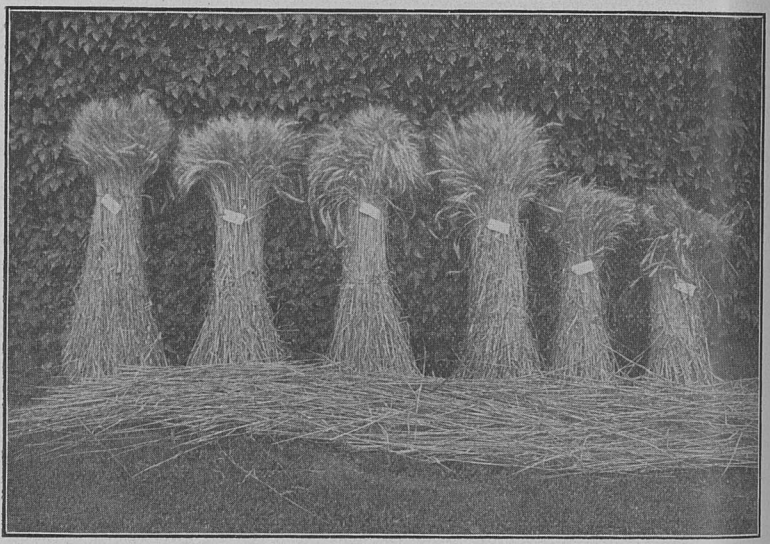
For two years past Mediterranean wheat has been grown on six plats of uniform quality prepared and fertilized each in a different manner. The nitrogen and protein content has been determined as indicated in connection with Table III. The protein content for 1902 was exceptionally high, though the yield was not so good as in 1903, when the protein content was much lower. The seasons seem to have had a determining influence on the protein content, rather than the fertilizers used or the treatment of the soil.

TABLE V—*Influence of fertilizers on the composition of Mediterranean wheat*

Plat No.	Treatment of the soil	1902			1903			Average yield of grain—bu.	Average yield protein two years—per cent
		Yield—bu.	Nitrogen—per cent	Protein—per cent	Yield—bu.	Nitrogen—per cent	Protein—per cent		
1	Bare fallow	11.66	2.81	19.86	17.81	1.92	13.62	14.74	16.74
2	Bare fallow + farmy'd m'n're	22.37	2.69	19.16	18.01	1.95	13.57	20.19	16.37
3	Bare fallow + complete fertil.	11.33	2.81	19.87	22.72	2.02	14.29	17.03	17.08
4	Peas plowed under	14.48	2.76	19.46	26.47	1.88	13.31	20.48	16.39
5	Peas under + farmy'd m'n're	26.00	2.85	20.18	29.58	1.87	13.24	27.79	16.71
6	Peas under + complete fertil.	17.50	2.78	19.68	28.33	2.06	14.54	22.92	17.11

The highest protein content, 20.18 per cent, in 1902, was obtained from the plat in which cowpeas were plowed under and farmyard manure was used at the rate of 15 tons per acre. This was but little better, however, than from bare fallow, which gave 19.86 per cent of protein. In 1903 the highest protein content, 14.54 per cent, was produced where cowpeas were plowed under and a complete fertilizer was used at the rate of 175 pounds per acre. This was almost one per cent higher than from bare fallow. A complete fertilizer and bare fallow produced a high protein content both

years—19.87 per cent in 1902 and 14.29 per cent in 1903. Taking the average of the two years' work cowpeas and a complete fertilizer gave the highest protein content, and bare fallow and a complete fertilizer closely followed. The averages for all plats are so close, however, that it can hardly be said that the composition was materially affected by the fertilizer or the soil treatment. It would be necessary to carry on this experiment a number of years for definite conclusions to be drawn. Experiments made in France by M. Gatelier* favor the idea that fertilizers and soil treatment influence the protein content of wheat; but as the experiments were not carried on through a series of years and as our results vary widely, it is not wise to conclude that such is always the case.



SEED SELECTION WITH MEDITERRANEAN WHEAT

The first two bundles to the left contain 900 large heads, the next two 1200 medium heads, and the last two 1600 small heads. Selections are annually made from these type heads. The results obtained are shown in Table VII

RELATIVE VALUES OF VARIETIES OF WINTER WHEAT FOR THE PRODUCTION OF FLOUR AND BREAD

In order to determine the relative values of the varieties of winter wheat grown on the Tennessee Experiment Station farm for several years past and compare these with standard varieties produced in other sections of the country, samples were sent to the Columbus Laboratories at Chicago to be milled and tested for flour and bread making purposes. Sam-

*"Increasing the Gluten in Wheat," M. Gatelier, president of the Agricultural Society, Maeux, France.

ples were sent of all the varieties grown on the Tennessee Station farm in 1902 and some of those grown in 1900 and 1901, besides a number of samples obtained from individual wheat growers in Tennessee. Through the courtesy of the directors of the Experiment Stations in Kentucky, Ohio, Oklahoma, Minnesota and Ontario, samples of standard wheats grown in those states were secured. These were forwarded to Chicago to be compared with our own for the purpose of determining more fully if possible the influence of soil and climate on the value of a variety for flour and bread production. In all, 85 samples were tested, as indicated in Table VI. The report of the Columbus Laboratories on the methods pursued in obtaining the results is herewith presented.

REPORT OF THE COLUMBUS LABORATORIES

"The accompanying results of our work on these wheats may be divided into three groups.

"1 Determinations upon the wheat direct.

"*a* The weight per measured bushel of the grain. This was determined upon the clean wheat by the use of a good grain tester of the usual construction as made for use in mills.

"*b* The number of kernels in 10 grams of the wheat was determined as being the best means of expressing the varying sizes of the kernels.

"*c* The amounts of flour produced are from results obtained by weighing the wheat to be ground and the products of milling.

"2 Determinations upon the flour expressed as direct percentages of the flour.

"*a* The ash is the mineral matter remaining after the careful burning in a muffle furnace of a suitable quantity of the flour. It is fairly constant for the flours of the different wheats, though there are some exceptionally high and some exceptionally low ashes for the grades of the flour produced.

"*b* The gluten was found by estimating the nitrogen by the Kjeldahl method and multiplying this nitrogen by the factor 5.7. This was found to be more constant and reliable for work of this character than the determination of the crude gluten by hand washing. In general the amounts of gluten in white flours as determined by the two methods are found to agree closely.

"*c* 'Absorption' expresses the amount of water it is necessary to add to different flours to make dough of uniform stiffness.

"3 Determinations on the flour expressed in percentages which have reference to the relations which certain qualities hold to similar qualities in some flour of known character. This flour may be called a standard flour. The standard flour used in connection with these samples is a blend of 15 winter wheat patent flours collected during the past season from representative mills located mainly in the Mississippi Valley. They include one flour from Tennessee. This blend of flours has a gluten content of 9.1 per cent, ash .33 per cent, and absorption 57.0 per cent. All of these qualities are lower for a patent flour than they would be for the total flour from the wheat obtained as in milling these samples. In addition to this the absorption of these flours is unusually high because of their having been very thoroughly dried out before grinding.

TABLE VI—*Relative values of varieties of winter wheat for production of flour and bread*

Number	Name of variety	Source of seed	Year grown	Weight per measured bu.—lbs.	Number of kernels in 10 grams	Per cent of flour produced	Per cent ash in flour	Per cent gluten in flour	Per cent absorption of flour	Per cent color	Per cent loaves per barrel	Per cent size of loaf	Per cent quality of gluten
1	Fulcaster	Tenn. Exp. Station	1902	60.0	231	73.4	55	13.0	60	96.0	101.9	97.4	83.7
2	Fulcaster	Tenn. Exp. Station	1900	55.5	277	72.2	52	12.4	62	95.0	103.2	96.1	85.0
3	Fulcaster	Tenn. Exp. Station	1901	59.0	285	70.0	52	11.4	62	98.0	103.2	98.7	89.2
4	Fulcaster	Hamblen Co., Tenn.	1902	62.0	238	74.0	43	11.4	62	98.0	103.2	96.1	87.6
5	Fulcaster	Sumner Co., Tenn.	1902	59.0	287	74.6	49	10.6	61	99.0	102.5	93 6	98.0
6	Fulcaster	Ky. Exp. Station	1902	59.0	228	74.6	53	11.2	61	98.5	102.5	96.1	88.4
7	Fulcaster	Okla. A. & M. Coll'ge	1902	62.0	272	75.0	48	13.6	62	94.0	103.2	96.1	81.6
8	Fulcaster	Rhea Co., Tenn.	1902	60.0	253	73.5	51	13.2	62	97.0	103.2	96.1	82.4
9	Mediterranean	Tenn. Exp. Station	1902	60.0	236	69.8	48	13.3	60	96.0	101.9	97.4	82.9
10	Mediterranean	Tenn. Exp. Station	1901	59.5	263	72.3	47	11.7	61	98.0	102 5	100.0	89 0
11	Mediterranean	Tenn. Exp. Station	1900	59.0	275	72.2	57	11.7	62	96.0	103.2	98.7	88.2
12	Mediterranean	Rhea Co., Tenn.	1902	60.0	267	70.0	50	10.4	60	98.0	101.9	94.8	90.6
13	Harvest King	Tenn. Exp. Station	1900	59.0	335	70.5	58	11.0	61	98.3	102.5	100.0	91.4
14	Harvest King	Tenn. Exp. Station	1901	58.5	299	69.3	45	9.9	60	99.5	101.9	100.0	96.0
15	Harvest King	Tenn. Exp. Station	1902	60.0	307	69.9	59	12.7	62	95.0	103.2	96.1	83.8
16	Harvest King	Ky. Exp. Station	1902	60.0	233	71.6	44	9.6	60	100.7	101.9	100.0	97.4
17	Harvest King	Warren Co., Tenn.	1902	58.5	296	70 4	43	10.2	59	99.5	101.2	97.4	93.0
18	Fultz	Tenn. Exp. Station	1960	60 0	308	69.1	50	11.9	60	96.0	101.9	94.8	85.4
19	Fultz	Tenn. Exp. Station	1901	60.0	303	68.7	46	10.1	60	99.7	101.9	97.4	93.4
20	Fultz	Tenn. Exp. Station	1902	60.5	294	68.7	58	11.8	60	96.0	101.9	96.1	86.4
21	Fultz	Kansas Seed House	1902	62.0	324	70.0	47	9.0	59	101.0	101.2	94.8	96.9
22	Fultz	Sumner Co., Tenn.	1902	59.5	323	72.3	47	10.5	59	98.0	101.2	96.1	90.8
23	Winter King	Tenn. Exp. Station	1900	60.0	287	68.9	56	10.8	59	100.0	101.2	96.1	90.0
24	Winter King	Tenn. Exp. Station	1901	56 5	314	67.5	54	10.5	59	100.5	101.2	93.6	89.2
25	Winter King	Tenn. Exp. Station	1902	59.5	281	71.9	53	10.5	59	100.0	101.2	96.1	90.9
26	New Columbia	Tenn. Exp. Station	1900	57.5	301	67.0	56	12.2	61	98.0	102.5	96.1	85.5
27	New Columbia	Tenn. Exp. Station	1901	57.5	292	70.0	54	10.4	60	100.0	101.9	93.6	89.7
28	New Columbia	Tenn. Exp. Station	1902	58.5	296	72.9	49	11.3	60	98.0	101.9	94.8	87.2
29	Poole	Tenn. Exp. Station	1902	60.0	276	69.9	49	10.5	59	100.0	101.2	96.1	90.8
30	Poole	Ohio Exp. Station	1902	61.0	244	70.4	44	9.7	60	98.3	101.9	100.0	97.0
31	Poole	Sumner Co., Tenn.	1902	56.5	359	68.7	50	10.4	60	99.3	101.9	96.1	91.3
32	Early Gen. Giant	Tenn. Exp. Station	1902	57.5	202	69.3	53	12.2	61	98 0	102.5	98.7	86.7
33	Early Gen. Giant	Ontario Agr. College	1902	61.0	212	70.8	44	10.2	60	100.0	101.9	98.7	93.7
34	Early Gen. Giant	Ky. Exp. Station	1902	57.0	247	70.4	48	9.8	60	101.0	101.9	97.4	94.7
35	Dawson's G. Chaff	Tenn. Exp. Station	1902	59.0	300	72.2	49	10.4	60	98.0	101.9	96.1	91.3
36	Dawson's G. Chaff	Ontario Agr. College	1902	61.0	227	71.0	48	8.4	59	101.0	101.2	93.6	99.1
37	Dawson's G. Chaff	Ky. Exp. Station	1902	58.0	254	71.6	47	8.1	58	101.2	100.6	96.1	103.2
38	Diamond Grit	Tenn. Exp. Station	1902	60.0	282	73.4	49	11.5	62	97.0	103.2	97.4	88.1
39	Diamond Grit	Ontario Agr. College	1902	63.0	239	71.0	42	11.7	59	98.5	101.2	96.1	86.7
40	Diamond Grit	Ky. Exp. Station	1902	59.0	290	71.0	45	10.4	60	99.0	101.9	102.6	95.5
41	Turkey Red	Tenn. Exp. Station	1902	62.0	344	74.6	55	11 3	62	96.0	103.2	100.0	90.3
42	Turkey Red	Okla. A. & M. Coll'ge	1902	63.0	357	73.4	51	13.4	61	94.0	102.5	97.4	82.7
43	Blue Ridge	Tenn. Exp Station	1902	58.0	270	72 2	50	12.3	60	95.5	101.9	100.0	87.0
44	Blue Ridge	Ohio Exp. Station	1902	60.0	231	71.6	56	11.8	60	96.0	101.9	100.0	93.7
45	Red Cross	Tenn. Exp. Station	1902	60.0	213	71.0	54	10.2	62	99.0	103 2	94.8	91.3
46	Red Cross	Ohio Exp Station	1902	60.0	237	71.6	46	10.2	58	99.3	100.6	96.1	92.1
47	Kan. Mortg. Lifter	Tenn. Exp. Station	1902	61.0	235	70.4	55	13.3	60	97.0	101.9	97.4	82.9
48	Niger	Tenn. Exp. Station	1902	61.5	214	73.4	61	12.0	61	97.0	102.5	96.1	85.5
49	Improved Poole	Tenn. Exp. Station	1902	60.5	244	68.7	51	12.2	59	97.5	101.2	97.4	85.9
50	Imp. Fulcaster	Tenn. Exp. Station	1902	60.0	258	68.7	47	13.0	60	97.5	101.9	96.1	83.0
51	Red Prolific	Tenn. Exp. Station	1902	61.0	301	68.1	53	11.0	61	97.0	102.5	97.4	90.0
52	Deitz Amber	Tenn. Exp. Station	1902	60.0	240	69.8	48	11.2	62	94.5	103.2	97.4	89.1
53	Egyptian	Tenn. Exp. Station	1902	61.0	290	68.7	48	12.6	60	97.0	101 9	97.4	85.0
54	Red May	Tenn. Exp. Station	1902	61.0	288	71.7	58	11.4	61	96.0	102.5	96.1	87.6
55	Currell's Prolific	Tenn. Exp. Station	1902	60.0	292	69.3	48	12.1	62	97.0	103.2	96.1	85.5
56	American Bronze	Tenn. Exp. Station	1902	59.0	261	69.9	53	11.3	59	98.0	101.2	93.6	86.4
57	Red Russian	Tenn. Exp. Station	1902	59.0	279	70.0	52	12.0	60	96.0	101.9	100.0	88.0
58	White Golden Cr's	Tenn. Exp. Station	1902	58.0	279	69.5	54	12.6	62	101.0	103.2	98.7	85.5
59	Mealey	Tenn. Exp. Station	1902	57.0	381	72.2	61	12.6	62	93.0	103.2	94.8	83.4
60	Blue Straw Fultz	Tenn. Exp. Station	1902	60.0	270	71.6	51	13.0	63	95.0	103.8	97.4	83.7
61	EarlyRed Clawson	Tenn. Exp. Station	1902	58.0	238	71.9	51	8.6	58	99.0	100.6	92.3	97.0
62	Velvet Chaff	Tenn. Exp. Station	1902	60.0	267	71.6	62	12.1	59	97.0	101.2	96.1	85.5
63	Perfection	Tenn. Exp. Station	1902	59.0	301	69.3	50	13.0	60	96.0	101.9	98.7	84.4
64	Early Ripe	Tenn. Exp. Station	1902	59.0	293	69.3	52	13.2	62	94.5	103.2	94.8	80.1
65	Rural N.-Y'r. No. 6	Tenn. Exp. Station	1902	56.0	254	69.3	61	12.7	62	95.0	103.2	98.7	85.2
66	Forty Fold	Tenn. Exp. Station	1902	58.0	276	71.7	60	10.1	58	99.0	100.6	94.8	91.7

TABLE VI—(*continued*)

Number	Name of variety	Source of seed	Year grown	Weight per measured bu.—lbs.	Number of kernels in 10 grams	Per cent of flour produced	Per cent ash in flour	Per cent gluten in flour	Per cent absorption of flour	Per cent color	Per cent loaves per barrel	Per cent size of loaf	Per cent quality of gluten
67	Rice Wheat	Tenn. Exp. Station	1902	59.0	272	69.9	52	13.1	62	97.0	103.2	97.4	83.4
68	Beardless Fulcast.	Tenn. Exp. Station	1902	59.5	290	70.5	51	13.5	60	99 0	101.9	97.4	82.4
69	Beech W.'s Hybrid	Tenn. Exp. Station	1902	60.0	274	69.8	53	13.1	60	99 0	101.9	98.7	84.1
70	Valley	Tenn. Exp. Station	1902	60.5	267	71.7	49	11.4	60	98.3	101.9	96.1	87.6
71	Democrat	Tenn. Exp. Station	1902	60.0	258	72.3	48	11.8	61	98.5	102.5	100.0	88.6
72	Gold Coin	Tenn. Exp. Station	1902	59.0	259	72.3	50	10.4	59	99.5	101.2	96.1	91.3
73	New Monarch	Tenn. Exp. Station	1902	59 0	250	71.1	51	10.3	60	98.5	101.9	94.8	90.8
74	Eclipse	Tenn. Exp. Station	1902	58.5	235	69.9	54	11.4	60	99.0	101.9	97.4	88.4
75	Early Pearl	Tenn. Exp. Station	1902	59.5	269	72.8	51	12.2	61	97.5	102.5	97.4	85.9
76	White Wheat No. 6	Tenn. Exp. Station	1902	59.0	291	72.8	58	10.0	59	100.0	101.2	96.1	93.0
77	Hopper	Tenn. Exp. Station	1902	60 0	245	71.0	50	12.3	62	98 0	103.2	97.4	85.6
78	California Red	Tenn. Exp. Station	1902	61.0	260	72.8	51	11.8	62	98.3	103.2	98.7	87.9
79	Lancaster	Tenn. Exp Station	1902	59.0	248	71.0	51	11.8	62	98.0	103.2	100.0	88.5
80	No. 4281	Tenn. Exp. Station	1902	59.0	264	71.0	55	10.5	62	99.3	103.2	98.7	92.5
81	No. 5342	Tenn. Exp. Station	1902	60 0	360	70.0	51	11.6	62	99.3	103.2	96.1	87.1
82	Wood Wheat	Hamblen Co., Tenn.	1902	60.0	222	73.2	51	9.2	59	100.5	101.2	100.0	99.3
83	No. 188 Spring	Minn. Exp. Station	1902	55.0	462	70.8	63	11.7	60	94.0	101.9	101.3	90.0
84	No. 146 Spring	Minn. Exp. Station	1902	54.0	454	72.2	58	13.3	60	94.0	101.9	102.6	85.5
85	No. 638 Spring	Minn. Exp Station	1902	62.0	267	74.4	51	9.2	61	97.0	102.5	98.7	98.5

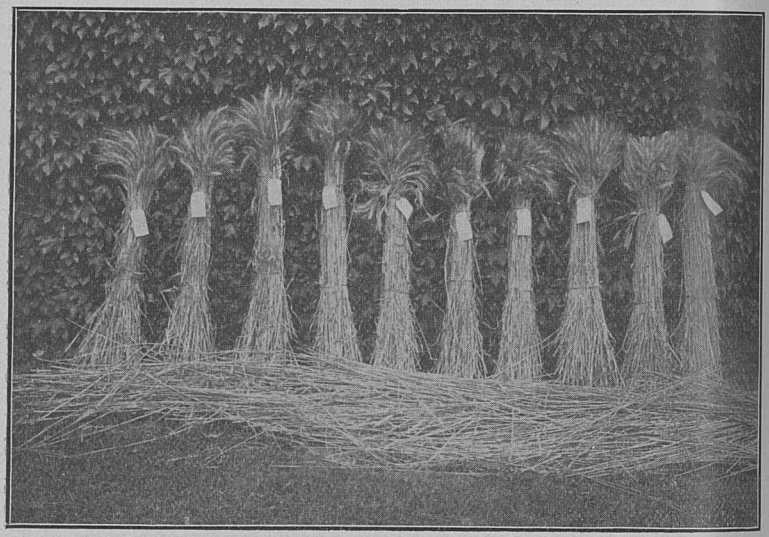
"*a* Color. This is a difficult thing to express concerning flour in an intelligible way to a person who has not seen the flour. Anyone familiar with flours knows that a patent flour from a soft winter wheat is much whiter in color than a flour from a spring wheat or a hard winter wheat. The latter is a more or less dark cream-yellow color, some spring patents being a very dark yellow. There are all graduations between these extremes. For convenience in designating these colors we have taken as one point in a scale of comparison the color of the blend of soft winter flours mentioned above, and as another point in the scale a standard Minneapolis patent flour from hard wheat. In this scale we have given the winter wheat patent a value of 100 per cent and the spring wheat patent a value of 97 per cent. Proper mixtures of the two have intermediate percentage values and the scale is extended on proportionate degrees both above and below these points. The variations in the colors of the flours from these wheats are designated in per cent, this scale of values being used. The whiter flours are the highest in the scale and the darkest are the lowest. Flour from No. 78 is almost snowy white. That from No. 84 is a very rich dark yellow.

"*b* The number of loaves from a barrel of flour will vary with the different methods of bread making used by different bakers. It is dependent upon the absorption of the flour and varies directly with that when the method of working the two flours is the same; and the number of loaves to the barrel therefore hold a different relation to each other for the different flours, and this relation is conveniently expressed in per cent.

"*c* The size of loaf which a flour would produce was determined by making a careful bake, in duplicate, under conditions which admitted of almost absolute control and in such a way that the size of the loaf could

be measured with great accuracy. The size of loaf is expressed in per cent of the size of a similar loaf baked under the same conditions from the standard winter wheat flour already mentioned.

"*d* Other things being equal, the size of a loaf of bread a flour will produce is dependent upon the amount and quality of the gluten. Two flours which are equal in the amount of gluten and similar in other respects will often produce loaves of different size and character because of a difference in the quality of gluten. The quality of gluten in this report is expressed as the relative capacity of a given weight of gluten to expand into a well risen loaf of bread. It is closely dependent upon the amount of gluten in the flour and the size of loaf which this flour will produce.



SEED SELECTION WITH MEDITERRANEAN WHEAT

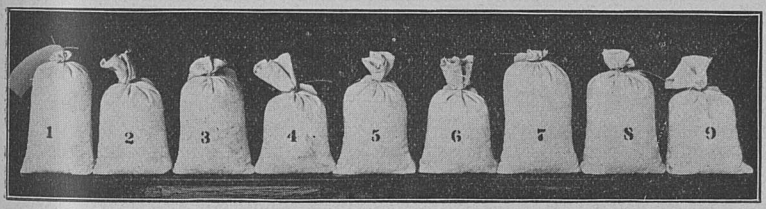
Reading from left to right the bundles represent (1) large grains, large heads; (2) small grains, large heads; (3) large grains, medium heads; (4) small grains, medium heads; (5) large grains, small heads; (6) small grains, small heads; (7) large grains; (8) small grains; (9) commercial sample; (10) sample bought. All selected by means of sieves—(7)-(10) without reference to size of head

"The mill in which the flour from these wheats was produced is equipped with an 'Invincible' wheat scourer; three pair of rolls made by the Allis-Chalmers Co.; a Whitemore middlings purifier; a Frazer & Mather flour bolter; and a Prinz & Rau 'Perfection' dust collector. These machines are all of a miniature pattern suitable for producing flour for a small quantity of wheat with the same degree of perfection as a mill of 1000 barrels daily capacity. To obtain the most satisfactory results in this mill, from six to ten pounds of wheat should be used. It was necessary to modify the method of milling somewhat to adapt it to these smaller samples of about two pounds each. The milling of these samples was so carried

on as to obtain very similar results for the different samples, but the amount of flour produced could not be measured with the same degree of accuracy as for the larger quantities of wheat. The wheat was so milled as to separate as completely as possible the bran and other offal from the flour material, and the flour analyzed was a blend of the entire flour produced from each sample. It corresponds closely to a straight grade of flour such as would be produced in a larger mill."

THE AUTHORS' COMMENTS

The amount of flour produced by Fulcaster under a variety of conditions ranged from 70 to 75 per cent, which makes it equal if not superior to the Minnesota spring wheat and the famous Turkey Red wheat grown so extensively in Kansas. It is also superior to the soft white varieties of wheat grown north of the Ohio and east of the Mississippi and in Canada. Among these are Early Genessee Giant, Dawson's Golden Chaff and Diamond Grit. Mediterranean also shows up very well, the Tennessee product averaging over 71 per cent. Poole grown in Tennessee produced as much flour as was obtained from the Ohio product, while Tennessee Fultz made as much as the Kansas sample. Tennessee Turkey Red wheat yielded as much flour as grain grown in Oklahoma.



BAGS CONTAIN EACH THE SAME NUMBER OF GRAINS. THEY REPRESENT THE 10 SELECTIONS OF MEDITERRANEAN WHEAT SEED AS SOWN, WITH THE EXCEPTION OF SAMPLE BOUGHT

For identification numbers see preceding illustration

As in all other instances there is considerable variation in the percentages of flour obtained. This would be expected, as the different varieties are not equally adapted to all sections; but it is rather surprising that what are regarded as leading varieties of wheat in other sections of the country, though not well adapted to local conditions, should not show a higher flour content when grown in those sections than when grown in Tennessee. One of the hard things to understand in connection with the table is that what have been commonly regarded as inferior varieties for Tennessee conditions show as high a flour content as the leading varieties. They can not be cultivated at the present time because the yield is unsatisfactory and the quality is more variable than that of the standard varieties.

Wheat varies widely in ash content. Some of the varieties from the Tennessee Station run very high and others run low, but they do not vary much more than those from any other section of the country. They are

probably higher on an average than those from Ohio, Kansas and Oklahoma. The Minnesota spring wheats are very high in ash. Compared with the standard of the Columbus Laboratories, the ash of all Tennessee wheats is very high.

The content of gluten in Tennessee wheats is very satisfactory. In only two instances does it fall below 10 per cent, being 9.9 in Harvest King and 8.6 in Early Red Clawson. In the majority of cases it is over 11 per cent and in a large number over 13 per cent. Fulcaster has a high gluten content and Mediterranean also shows up well. Poole is considerably lower than either of these. Other varieties that possess a high gluten content are Kansas Mortgage Lifter, Blue Straw Fultz, Perfection, Early Ripe, Rice Wheat, etc. While these varieties have a gluten content equivalent to that of the leading varieties and higher than some of them, they are not regarded as of special merit for cultivation in Tennessee. They bear witness to the fact that the climate is adapted to the production of a wheat high in gluten. The leading Tennessee varieties of wheat yielded as much gluten as the famous Turkey Red or any of the Minnesota hard spring wheats. They are decidedly superior to the soft wheats, such as Early Genessee Giant and Dawson's Golden Chaff, grown so largely in the East. The results set forth in the table fully substantiate the strong claims made for Tennessee as a section adapted to the growth of wheat rich in gluten.

The absorptive capacity of Tennessee flours is satisfactory, being equal or superior to that of the Minnesota varieties or the standard varieties grown in various other sections of the country. The absorptive capacity of Fulcaster is high, ranging from 61 to 62 in nearly all instances. Poole and Mediterranean also show up well, as do a number of varieties that would not be classed as leading ones.

As a safe rule it may be said that the hardest wheats produce a darker flour than the softer wheats. The Tennessee hard wheats, as Fulcaster and Mediterranean, do not class as high in color as Early Genessee Giant, Dawson's Golden Chaff, Winter King, and Poole. These softer, whiter wheats can be grown in Tennessee with satisfaction, especially Poole and Harvest King. The Tennessee hard wheat in a majority of the varieties produced a flour of as good quality as the Minnesota spring wheat or any hard wheat recognized as a standard variety in other sections of the country.

On this point Professor G. L. Teller of the Columbus Laboratories comments as follows:

"Almost any sound flour which has been so milled as to produce a fairly clear color, showing that the bran has been well removed, can be made into good white bread if proper methods of working have been pursued. The quality of flour which a bread baker selects is one that will take a large proportion of water, will produce a loaf of good size, and will have a fairly good color in the loaf when it is baked. Well milled flours from even the darkest wheats become much whitened during baking. A very starchy flour is not suited to the needs of the bread baker but it is adapted to the making of pastry. Flours which are low in gluten are generally classed as starchy flours. Starchy flours have a low absorption and are very white in color. Many of them are adapted to the needs of the cracker baker and find a large sale in some localities for this purpose.

"For general domestic purposes a flour is preferred which contains a reasonable amount of gluten of good quality, is fairly white in color and yet is not so harsh in the dough as those flours which are made from the very hard wheats. A flour of this character is adapted for the making of bread, biscuits and pastry as they are usually made by the housewife."

So far as the per cent of loaves to a barrel of flour is concerned, Fulcaster is a distinct leader, with Mediterranean second and Poole a close third. These three are equal or superior to Minnesota spring wheat and rank alongside of Turkey Red. Fulcaster especially is superior to the soft white wheats grown in the East or to any of the softer wheats that can be produced to advantage in Tennessee. So far as the size of loaf is concerned, Mediterranean and Turkey Red have possibly a slight advantage over Fulcaster. Tennessee wheat as a rule stands very well, averaging well up to 97 per cent for all the varieties.

In the quality of gluten Dawson's Golden Chaff seems to be a leader. Considering all the tests made Fulcaster can be classed only as medium. According to these tests it is not equal to Poole, the Minnesota spring wheat, Early Genessee Giant or Dawson's Golden Chaff. Some other of the softer varieties grown in Tennessee, as Winter King, etc., are also superior to it. It seems to be equal to Turkey Red and all of the other essentially hard red varieties in quality of gluten, which seems from the table to be an element in which the hard winter wheats are somewhat deficient.

On the whole the quality of the gluten is satisfactory, averaging between 85 and 90 per cent, which, considering the large number of samples tested from Tennessee and the small number from other sections of the country, may be regarded as very satisfactory until further tests throw more light on the subject.

Professor Teller offers the following helpful suggestions on this point, which make it clear that although Fulcaster and Mediterranean have not so high a quality of gluten as some of the softer white wheats they are decidedly more valuable because of the much higher per cent contained and the large number of bushels of grain they produce owing to their special adaptation to Tennessee climatic conditions. (This explanation is inserted to prevent a misconception on the part of the reader regarding hard wheats):

"When the proper methods of working are pursued the size of the loaf is dependent upon two factors: the amount of the gluten and the quality of the gluten. Of two flours which have the same amount of gluten that which has gluten of the highest quality will make the largest loaf. Of two flours which have gluten of the same quality that which has the largest amount of gluten will make the largest loaf.

"In milling these wheats all the flour produced from each is united into one blend which may properly be called a straight grade of flour. In actual milling practice the flour produced from a wheat is generally divided into two or more grades the exact nature of which will depend upon circumstances. Among these grades the highest, usually called the 'patent,' will contain less gluten than the lower grades of flour and the gluten will be of a higher quality. Whether or not the patent flour will make a larger loaf than the straight flour from the same wheat will depend upon how

100 average heads grown from large grains, large heads

100 average heads grown from large grains, medium heads

100 average heads grown from large grains, small heads

100 average heads grown from sample bought

SEED SELECTION WITH MEDITERRANEAN WHEAT

the quantity and quality of the gluten balance each other. It is quite consistent, then, with what we should expect that some of these softer wheats with their small amount of gluten of a high quality show a somewhat larger loaf volume in the straight grade of flour than the harder wheats with the larger amount of gluten. And this explains the apparent discrepancy between the results as given in the table of analyses and the common experience stated by millers that the Mediterranean and Fulcaster wheats are among those most highly esteemed for bread making purposes.

"In the patent flours from the soft wheats containing a small quantity of gluten the amount of gluten is so reduced that they are unable to give the best results in bread making, and this in spite of the fact that this gluten is of a high quality. In the harder wheats with their large amount of gluten the gluten in the patent flour is still sufficient to give excellent results and the quality of the gluten is materially improved over that of a straight flour. The same principle may be applied to other wheats of the group, so that in general those wheats which have the largest amount of gluten in the flours are those which, other things being equal, should be the most highly prized.

"The results of the analyses show the flours from the wheats grown at the Tennessee Experiment Station to be high in gluten relative to flour from wheats of the same character which are grown in many other sections of the United States and Canada, especially those sections lying north of the Ohio and east of the Mississippi river. This is seen in the analyses also with regard to those grown in parts of Kentucky. In nearly every instance the flour from the wheats grown at the Tennessee Experiment Station contain more gluten than that from the same variety of wheat grown at the Kentucky Experiment Station. Especially worthy of note are the results on Dawson's Golden Chaff. The flour from that grown in Tennessee contains 10.4 per cent gluten, from that grown in Kentucky 8.1 per cent, and from that grown in Ontario 8.4 per cent."

The milling and baking tests are very favorable to the varieties produced in Tennessee. In all respects but one Fulcaster has shown itself to be a leading wheat, not only well adapted to Tennessee conditions but for culture over a large section of the country. Poole and Mediterranean also stand high, and as they have the merit of producing large yields and being admirably adapted to the soil and climatic conditions, they seem to be varieties that should be extensively cultivated in the South in view of all the information obtainable.

SEED SELECTION

Mention has already been made of the importance of standardizing and selecting those varieties best adapted to a given locality before attempting to improve them by crossbreeding. Several objects have been in view in the selection experiments conducted on the Station farm. Among these have been, first, to determine by actual test the best present method for the farmer to pursue in order to maintain and increase the yield of wheat grown on his farm; second, to compare large and small grains from large, medium and small heads with large grains, small grains, commercial sample,

TABLE VII—*Seed selection with Mediterranean wheat*

Plat No.	Method of selection	Date of seeding—Oct.	No. of seeds sown per plat	Average No. of grains per head and ounce as sown								Height of crop, 1903—inches	Date of ripening—June, 1903	No. of heads per four square feet, 1903	Total weight of crop, 1903—lbs.	Weight of grain, 1903—lbs.
				1901		1902		1903		Average						
				Head	Ounce	Head	Ounce	Head	Ounce	Head	Ounce					
	I *Large heads*															
1	Large grains	16	11818	28.7	567	24.30	600	28.01	622	27.00	596	54	11	161	9300	2418.7
2	Small grains	16	11818	28.7	732	25.40	803	28.22	724	27.44	753	54	11	163	9200	2375.0
	II *Medium heads*															
3	Large grains	16	11818	16.1	615	18.66	630	23.50	634	19.42	626	54	11	160	9600	2300.0
4	Small grains	16	11818	16.1	764	20.41	798	25.45	726	20.65	763	54	11	150	8900	2175.0
	III *Small heads*															
5	Large grains	16	11818	11.2	658	11.37	760	11.01	719	11.19	712	52	11	139	7950	1950.0
6	Small grains	16	11818	11.2	835	11.10	937	12.03	887	11.44	886	51	11	135	7300	1868.7
	IV *General selection*															
7	Large grains	16	11818	.....	567	.....	625	.....	628	.....	607	51	11	135	7550	2087.5
8	Commercial sample	16	11818	.....	673	.....	745	.....	649	.....	689	52	11	143	7500	2068.7
9	Small grains	16	11818	.....	970	.....	825	.....	850	.....	882	49	11	159	7100	1887.5
10	Sample bought	16	11818	.....	.....	.....	656	.....	.....	.....	.....	49	11	128	5850	1762.5

TABLE VII—*Seed selection with Mediterranean wheat (continued)*

Plat No.	Method of selection	Average No. of grains per head and oz. as harvested								Yield of grain and straw								Ratio of grain to straw, 1903
		1901		1902		1903		Avg.		1901		1902		1903		Avg.		
		Head	Ounce	Head	Ounce	Head	Ounce	Head	Ounce	Grain—bu.	Straw—tons	Grain—bu.	Straw—tons	Grain—bu.	Straw—tons	Grain—bu.	Straw—tons	
	I *Large heads*																	
1	Large grains	17.6	712	24.0	692	17.71	832	19.77	745	29.3	2.12	27.50	1.50	40.31	3.44	32.37	2.35	1:2.40
2	Small grains	16.4	787	24.4	688	18.80	872	19.87	782	22.7	1.76	23.40	1.36	39.58	3.41	28.56	2.18	1:2.54
	II *Medium heads*																	
3	Large grains	19.4	705	24.0	652	16.91	870	20.10	742	29.3	2.04	30.41	1.63	38.33	3.65	32.68	2.44	1:2.40
4	Small grains	18.4	730	23.9	667	18.53	850	20.28	749	29.0	2.13	27.80	1.36	26.25	3.36	31.01	2.28	1:2.45
	III *Small heads*																	
5	Large grains	18.4	760	23.1	679	17.88	860	19.79	766	28.8	2.21	24.60	1.13	32.50	3.00	28.63	2.11	1:2.45
6	Small grains	18.3	750	22.9	681	18.29	885	19.83	772	26.1	2.18	20.00	.90	31.14	2.72	25.75	1.93	1:2.49
	IV *General selection*																	
7	Large grains	19.3	682	23.8	668	.....	.....	21.55	675	30.4	2.27	20.60	.88	34.79	2.73	28.60	1.96	1:2.20
8	Commercial sample	16.0	766	24.6	732	19.00	815	19.87	771	22.9	1.84	20.60	1.08	34.47	2.72	26.00	1.88	1:2.42
9	Small grains	18.1	732	23.4	689	.....	.....	20.75	710	24.5	1.85	14.30	.70	31.46	2.61	23.42	1.72	1:2.44
10	Sample bought	14.7	800	23.7	712	18.23	850	18.87	787	22.6	1.56	16.00	.75	29.37	2.04	22.66	1.45	1:2.14

and sample bought; third, to increase the vigor and stooling qualities of the wheat and fix a more nearly uniform type of head; fourth, to cross these varieties after they have been improved by selection. It is well to remember that while seed selection is a matter of very great importance improvements come slowly and not suddenly as some people are disposed to believe. It takes many years of careful work to bring about the desired improvements.

Three of our best varieties have been chosen for this work—Fulcaster, Mediterranean and Poole. Fulcaster is a good variety in many respects. It possesses a stiff straw, does not shatter, is a good milling wheat, and yields freely. For three years it made larger yields than any other variety grown. Mediterranean resembles Fulcaster very much in its character of growth, but it is not quite so stiff in the straw. It does not shatter and has the highest protein content of all the varieties grown for four years. The millers esteem it a leading variety for flour production. Poole wheat heads the list in point of yield for four years. It has always yielded well and on that account was chosen for this work. Its weak points are its tendency to shatter and its rather low percentage of flour and protein.

Investigations are now undertaken to study the individuality of heads of wheat from these varieties, and selections will be made from those plants only that are vigorous and stool freely. The importance of those features of the work, and in fact of all the selection experiments, is borne out by the series of half-tones illustrating the bulletin. The work is being elaborated each year. It now covers a rather comprehensive field, which will be enlarged in the future as means and opportunity permit.

After these investigations have been carried on for a sufficient length of time and satisfactory improvements have been made, crossbreeding experiments will be instituted for the purpose of ingrafting new and desirable qualities into these several varieties. The object of the work is to secure new and better varieties of wheat for distribution to the farmers of Tennessee.

The method of selection pursued with Mediterranean is presented in Table VII. The full data for Mediterranean is presented so that anyone interested can understand the methods followed. The table relative to Poole has been omitted for want of space.

Much has been said and written on the subject of seed selection and great claims have been made regarding the increased yield from the use of large and plump grains of wheat. It has been thought that the farmer could easily increase the yield of wheat by simply selecting out choice large heads for a few years. This is true to a limited extent; but after three years of careful selection at the Station it is evident that in order to improve a variety by selection from the head the work must be very carefully done for many years, and it is believed that there are comparatively few farmers who will be sufficiently accurate to do this kind of work satisfactorily. To select as indicated simply with a view to increasing the present yield would hardly pay for the labor and expense involved. The Station can do the work to better advantage and save the farmer much annoyance. On the other hand, it will often pay the farmer to select from the head as indicated to keep his wheat pure and vigorous.

Selecting out the large grains by means of sieves is probably the best method for the farmer to practice in keeping up the yield and improving the quality of his wheat. No good farmer will neglect to look carefully after the grading of his wheat, for the largest and plumpest berries always give the best results. These berries are produced chiefly by the large and medium heads. If this simple method is followed systematically the yield and quality of the wheat can no doubt be increased. The improvement may possibly be rapid the first year or two, but for several years after will be

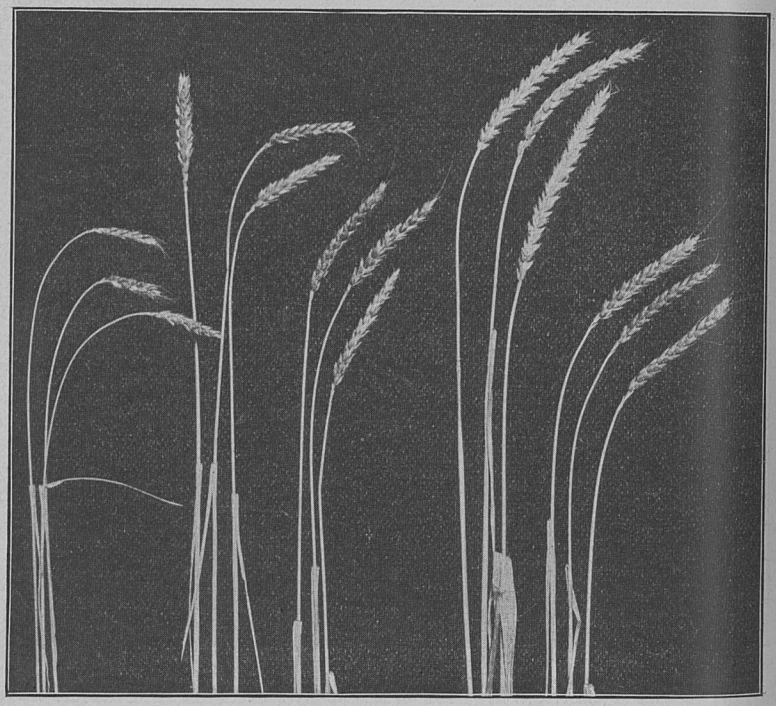
SHOWING THE VARIATION IN TYPE OF HEAD AND NUMBER OF STOOLS PRODUCED FROM A SINGLE GRAIN OF POOLE WHEAT

Reading from left to right—heads too small, three good heads, heads too coarse and open

hardly perceptible. The slow improvement has led many farmers to believe that the practice is not a profitable one, although it does prevent varieties from running out and lessens the necessity of purchasing new and untried varieties at big prices. It has not appeared from the trials made at the Station farm that much larger yields are obtained from large grains than from well graded commercial samples of wheat. The comparison usually made is between very small grains and very large grains, but that is

hardly fair, since it rarely happens in actual farm practice that in a quantity of seed taken at random all the grains are either very small or very large.

The average difference in yield at the end of three years between large grains—607 per ounce,—commercial sample—689 per ounce,—and small grains—882 per ounce, with Mediterranean wheat, was 2.60 bushels in favor of large grains as compared with the commercial sample, and 5.18 bushels in favor of large grains over small grains. The difference in yield between the large grains and commercial sample chiefly occurred the first year; but it is possible though hardly probable that the difference was partly due to the variation in the soil. The experiment has been carried on in a



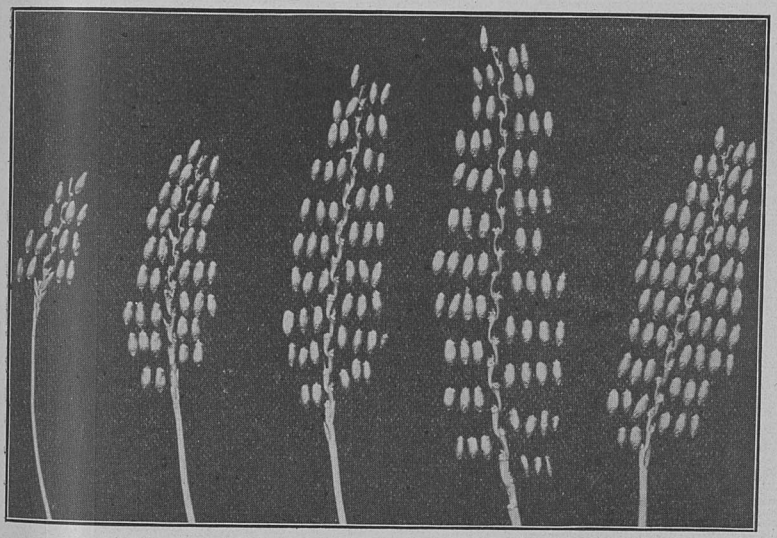
VARIOUS FORMS OF HEAD SHOWN BY POOLE WHEAT

Reading from left to right—heads too small, too short, too tapering, too long and open, proper shape

different part of the field for the last two years and the difference in yield is now only .32 bushel per acre in favor of the large grains. The farmer and the experimenter must remember that this kind of work, whether the selection is made from the grain itself or from the best type heads, pays only when the work is carefully done and is carried on continuously without change for many years, or until a definite type is fixed. Many farmers are unwilling to take the extra trouble necessary unless they are assured of

several bushels of increase with the first year or so. This will seldom if ever be obtained with winter wheat, for it does not yield as readily to improvement as some other grains if the variety is thoroughly acclimated and suited to its environment.

The yields of large and small grains from large, medium and small heads for three years were as follows: Of the large grains from medium heads there were 626 grains per ounce and 19.4 grains per head, and they made the largest yield, 32.68 bushels per acre. Of the large grains from large heads there were 596 grains per ounce and 27 grains per head, and the yield was a close second, 32.37 bushels per acre, which proves that it is not so important to choose the very largest heads for this kind of work as has generally been believed. In fact, it is a mistake to make extreme selections, for the tendency in an abnormally developed product is both to



THRESHED HEAD OF EACH OF THE TYPES OF POOLE WHEAT SHOWN ON OPPOSITE PAGE

vary and to revert. The progeny is not so vigorous as from medium-sized plants or heads, and hence is more readily attacked and injured or destroyed by insects or fungous diseases. The quality of abnormally developed types is not as a rule equal to that of the smaller ones and it is more difficult to maintain; for having been produced artificially it must be maintained artificially. Selections from medium-sized heads and plants are most likely to give satisfactory results. Notice the illustrations relative to the type heads of Poole wheat; also the variations in the character of stool produced by a single grain. It would be unwise, for the reason set forth, to select from either the largest head or the largest stool. Observe that the largest head contains but few more berries than the shorter, more compact, head, and

that the grains are more regular in size and distribution in the medium head, which gives it better "balance." Selections should follow the happy medium and so avoid extremes with their attendant ills.

The large grains have always had the advantage over the small grains in point of yield, although in some cases the difference was very slight. The average for three years is decidedly in favor of the large grains, except in the case of the small grains from medium heads, which yielded surprisingly well. There is a difference of 3.77 bushels per acre in favor of large grains from large heads and 4.08 bushels per acre in favor of large grains from medium heads, over large grains; and 6.37 bushels per acre in

TABLE VIII—*Fertilizer experiments with winter wheat on impoverished soil after bare fallow*

Plat No.	Kind of fertilizer	Amount of fertilizer applied per acre—lbs.		1902 Yield per acre		1903 Yield per acre		Avg. yield per acre		Increase over no fertilizer		Average increase over no fertilizer—bu.	Cost of fertilizer per acre, 1903	Cost of bushel of increase	
		1901	1902	Grain—bu.	Straw—tons	Grain—bu.	Straw—tons	Grain bu.	Straw—tons	1902 Grain—bu.	1903 Grain—bu.			1902	1903
1	No fertilizer			11.66	.80	17.81	1.20	14.74	1.00						
2	Farmyard manure	*15		22.37	1.27	18.01	1.22	20.19	1.25	+10.71	+ .20	5.46	$2.00	$0.37	
3	Nitrate of soda	150	150	6.66	.47	20.63	1.38	13.65	.93	— 5.00	+2.82		3.75		$1.33
4	Cotton-seed meal	300	300	8.96	.62	22.91	1.46	15.94	1.04	— 2.70	+5.10	1.20	3.60		.70
5	Acid phosphate	300	300	12.50	.69	19.58	1.14	16.04	.92	+ .74	+1.77	1.26	1.80	2.43	1.02
6	Bone meal	300	300	13.96	.88	22.08	1.30	18.02	1.09	+ 2.30	+4.27	3.29	4.50	1.96	1.05
7	Muriate of potash	75	75	12.08	.85	20.41	1.49	16.25	1.17	+ .42	+2.60	1.51	1.88	4.48	.72
8	Nitrate of soda	75	75	11.18	.81	22.30	1.47	16.74	1.14	— .48	+4.49	2.01	2.78		.62
	Acid phosphate	150	150												
9	Blood and bone	225	300	12.91	.88	20.83	1.50	16.87	1.19	+ 1.35	+3.02	2.19	3.75	2.08	1.24
10	Nitrate of soda	75	75	12.37	.81	23.12	1.63	17.74	1.22	+ .76	+5.31	3.04	3.11	4.09	.58
	Muriate of potash	50	50												
11	Acid phosphate	150	150	11.03	.75	20.83	1.50	15.93	1.13	— .63	+3.02	1.20	2.14		.70
	Muriate of potash	50	50												
12	No fertilizer			11.66	.80	17.81	1.20	14.74	1.00						
13	Farmyard manure	15		22.37	1.27	18.01	1.22	20.19	1.25	+10.71	+ .20	5.46	2.00	.37	
14	Nitrate of soda	50	50	11.33	.68	22.72	1.54	17.03	1.11	— .33	+4.91	2.29	2.47		.50
	Acid phosphate	100	100												
	Muriate of potash	25	25												
15	Cotton-seed meal	100	100	9.16	.66	22.50	1.59	15.83	1.13	— 2.51	+4.69	1.10	2.42		.51
	Acid phosphate	100	100												
	Muriate of potash	25	25												
16	Lime	†25		9.66	.70	21.46	1.28	15.56	.99	— 2.00	+3.65	.83	.46		.12

*Tons. †Bushels.

favor of large grains from large heads and 6.68 bushels per acre in favor of large grains from medium heads, over the commercial sample. The increase in yield obtained to date would not pay for the labor involved in making the selections except for the fact that the Station is in a position to continue the work until vigorous plants have been produced of a well defined type. It might seem at first that the results obtained are unsatisfactory, considering the amount of work involved, but on close examination it will be noticed that if large grains from medium heads are taken as a standard all the selections from small grains except small grains from large heads show a decided difference in point of yield at the end of three years as compared with the first year.

FERTILIZERS ON BARE FALLOW

Fertilizer experiments with winter wheat on an impoverished soil after bare fallow have now been carried on for two years. The average of the results obtained is found in Table VIII. Sixteen plats were used in the work, two of them being check plats to which no fertilizer was applied. The fertilizers most commonly applied in the State were used in amounts which experience seemed to indicate would be most likely to give profitable returns. So far as known this piece of land never had any fertilizer on it previous to the commencement of the experiment, and it certainly was a very poor soil and was in very bad mechanical condition. It has been plowed soon after harvest each year and summer-fallowed and a good seed-bed has been prepared. The fertilizer has then been applied broadcast

FERTILIZER EXPERIMENTS WITH WINTER WHEAT AFTER BARE FALLOW

and worked well into the soil several days before seeding the crop. The nitrate of soda has been put on at two applications, fall and spring. Cotton-seed meal and lime should always be applied well away from the seed, as they are liable to injure its germinating power if they come into contact with it. The fertilizers were scattered broadcast and worked into the soil with a harrow.

The largest increase over no fertilizer obtained from any application in 1902 or 1903 was from farmyard manure, 10.71 bushels. It gave only .20 bushel of increase over no fertilizer in 1903. The season was a more favorable one for wheat and that accounts for the large yields obtained that year. In a bad season the fertilizer would probably have done better, and especi-

ally the farmyard manure with its supply of vegetable matter, which would have enabled the soil to retain a larger amount of water.

Many of the fertilizers failed to give a profit in 1902. Among these were nitrate of soda, cotton-seed meal, and lime. Those giving an increase were acid phosphate, .74 bushel; bone meal, 2.30 bushels; and blood and bone, 1.35 bushel. These increases were so small that the cost of a bushel of increase was out of all proportion to the benefit derived. It was lowest from farmyard manure, 56 cents per bushel, near to the market price of wheat. With all other fertilizers, either singly or combined, it ranged above $2, a prohibitive sum.

TABLE IX—*Fertilizer experiments with winter wheat on impoverished soil after peas under*

Plat No.	Kind of fertilizer	Amount of fertilizer applied per acre—lbs.		1902 Yield per acre		1903 Yield per acre		Avg. yield per acre		Increase due to fertilizer		Increase from peas under and fertilizer		Avg. difference due to peas under; grain—bu.	Cost of fertilizer per acre, 1903	Cost of a bushel of increase	
		1901	1902	Grain—bu.	Straw—tons	Grain—bu.	Straw—tons	Grain—bu.	Straw—tons	1902 Grain—bu.	1903 Grain—bu.	1902 Grain—bu.	1903 Grain—bu.			1902	1903
1	No fertil....	.....	.....	14.48	1.00	26.47	1.88	20.48	1.44	.....	.....	.....	.....	5.74	.....	.....	.....
2	F'y'dm're	*15	....	26.00	1.21	29.58	2.23	27.79	1.72	+10.71	+ .20	+11.52	+3.11	7.60	$2.00	$0.35	$0.64
3	Nit. of soda	150	150	17.08	1.03	29.58	1.61	23.33	1.32	— 5.00	+2.82	+ 2.60	+3.11	9.68	3.75	1.44	1.20
4	C.-S. meal..	300	300	14.16	1.03	28.33	2.20	21.25	1.62	— 2.70	+5.10	— .32	+1.86	5.31	3.60	.....	1.93
5	Acid Phos..	300	300	16.25	1.05	30.00	2.25	23.13	1.65	+ .74	+1.77	+ 1.77	+3.53	7.09	1.80	1.00	.51
6	Bone meal	300	300	19.36	1.16	32.91	2.51	26.14	1.84	+ 2.30	+4.27	+ 4.88	+6.44	8.12	4.50	.92	.70
7	Mu. of Pot.	75	75	17.75	1.11	28.75	2.09	23.25	1.60	+ .42	+2.60	+ 3.27	+2.28	11.43	1.88	.57	.82
8	Nit. of soda	75	75	19.78	1.01	32.08	2.54	25.93	1.78	— .48	+4.49	+ 5.30	+5.61	9.19	2.78	.52	.50
	Acid Phos.	150	150	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
9	Bl'd & bone	225	300	17.28	.95	31.05	2.54	24.17	1.75	+ 1.35	+3.02	+ 2.80	+4.58	7.30	3.75	1.34	.82
10	Nit. of soda	75	75	22.91	1.20	32.30	2.67	27.61	1.94	+ .76	+5.31	+ 8.43	+5.83	9.86	3.11	.37	.53
	Mu. of Pot.	50	50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	Acid Phos.	150	150	22.08	1.16	31.66	2.48	26.87	1.82	+ .63	+3.02	+ 7.60	+5.19	10.94	2.14	.28	.41
	Mu. of Pot.	50	50	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
12	No fertil ...	.....	.....	14.48	1.00	26.47	1.88	20.48	1.44	.....	.....	.....	.....	5.74	.....	.....	.....
13	F'y'd m're..	*15	..	26.00	1.21	29.58	2.23	27.79	1.72	+10.71	+ .20	+11.52	+3.11	7.60	2.00	.35	.64
14	Nit. of soda	50	50	17.50	1.10	28.33	2.16	22.92	1.63	+ .33	+4.91	+ 3.02	+1.86	6.39	2.47	.82	1.33
	Acid Phos...	100	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Mu of pot.	25	25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
15	C.-S. meal	100	100	18.53	.95	27.71	2.09	23.12	1.52	— .25	+4.69	+ 4.05	+1.24	7.19	2.42	.60	1.95
	Acid Phos .	100	100	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	Mu. of Pot.	25	25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
16	Lime.....	†25	....	14.16	.87	30.42	2.09	22.29	1.48	— 2.00	+3.65	— .32	+3.95	6.73	.46	.....	.11

*Tons. †Bushels.

In 1903 a much more satisfactory increase was obtained from the use of fertilizers alone. Nitrate of soda and muriate of potash gave an increase of 5.31 bushels, cotton-seed meal 5.10 bushels, and both mixtures of complete fertilizer about 5 bushels. Phosphate and potash singly did not do very well; but when combined with nitrate of soda in a complete fertilizer good results followed, the most profitable increase, 4.91 bushels, being obtained from a mixture of 50 pounds of nitrate of soda, 100 pounds of acid phosphate and 25 pounds of muriate of potash. The cost of a bushel of increase in this instance was 50 cents.

Farmyard manure gave the largest increase of grain for both years at the least cost, 55 cents per bushel. Although lime showed a loss in 1902 it gave an increase in 1903 of 3.65 bushels at a cost of 12 cents, and it is evidently a very good fertilizer for the type of soil under discussion.

Next to farmyard manure and lime would come a complete fertilizer. Applications of cotton-seed meal would then be in order, though the cost is too great to justify its use very extensively. The prices at which the fertilizer constituents are figured are shown at the bottom of the table for the guidance of the reader.

FERTILIZERS WITH COWPEAS PLOWED UNDER

Fertilizer experiments have been carried on for two years with winter wheat on impoverished soil with cowpeas plowed under. The same kinds

Fertilizer Experiments with Winter Wheat after Cowpeas Plowed Under

and amounts of fertilizer have been used as on bare fallow. As soon as the wheat was harvested the ground was broken and peas were sown. These were plowed down about September 15 and the land was put into condition for seeding to wheat. The fertilizers were applied as in the previous instance. The largest increase where cowpeas were plowed under in 1902 was 11.52 bushels, and came from the addition of 15 tons of farmyard manure. This was less than one bushel more than that obtained from the use of farmyard manure after bare fallow—a fact showing that more vegetable matter was added to the soil than the crop could utilize.

Notice that a fairly good increase was obtained after the plowing down of cowpeas with many of the fertilizers that showed a decrease on bare fallow. Nitrate of soda and muriate of potash on bare fallow gave an increase of .76 bushel, whereas after cowpeas plowed under they gave an increase of 8.43 bushels. Nitrate of soda and acid phosphate, which showed a loss in 1902 on bare fallow, gave an increase of 5.30 bushels after cowpeas plowed under. Good results were also obtained from the use of acid phosphate and muriate of potash, the increase being 7.60 bushels. The cost of a bushel of increase was also much less where the cowpeas and fertilizer were used together than after bare fallow. The cheapest bushel of increase was made from the use of acid phosphate and muriate of potash at a cost of 28 cents; followed by nitrate of soda and muriate of potash—37 cents—and nitrate of soda and acid phosphate—52 cents. Farmyard manure and cowpeas gave a bushel of increase for 35 cents; muriate of potash alone for 57 cents.

In one column of the table is shown the increased yield obtained from plowing under cowpeas over the use of fertilizers on bare fallow. A decided benefit is shown from the use of cowpeas for two years, the increase ranging from 5.74 bushels where no fertilizer was applied to 11.43 bushels where muriate of potash was used. It would therefore seem reasonable to suppose that a crop of cowpeas plowed down on such ground would give an increase of about six bushels of wheat per acre. As the ground is poor and does not make a large crop of peas, this is a fair increase. It is also clear that cowpeas must be plowed down on some kinds of land to bring them into condition for the profitable culture of wheat and in order that the fertilizers applied may give a profitable return.

SUMMARY

1 Of the 48 varieties of wheat grown on the Station farm for the past four years a limited number only can be recommended for general culture.

2 Poole made the highest yield in 1903—48.5 bushels; the average for four years was 37.23 bushels. Niger made 44.27 bushels in 1903 and averaged 36.77 bushels for four years. Fulcaster produced 39.27 bushels in 1903 and averaged 36.2 bushels for four years. Mediterranean made 42.55 bushels in 1903 and averaged 36.18 bushels for four years.

3 Early Red Clawson, White Wheat No. 6, Winter King, Eclipse, New Monarch, Gold Coin, Dawson's Golden Chaff, American Bronze and Beardless Fulcaster have been discarded after four years' trial as unsuitable varieties for this State.

4 Poole is the only variety brought from outside the State that can be recommended for general culture.

5 Some of the reasons for the low yields reported by Tennessee farmers are, a failure to rotate and to prepare the seed-bed properly, a deficiency of vegetable matter in the soil, late seeding, and unsuitable varieties.

6 The climate and soil of Tennessee favor the production of wheats containing a very high percentage of protein. The average percentages of protein in Mediterranean and Fulcaster were 17.39 and 17.00, respectively, at the end of four years. All the varieties were high, Dawson's Golden Chaff being lowest, with 13.19 per cent.

7 The season has a marked influence on the protein content. Beech Wood's Hybrid contained 21.92 per cent in 1900, 13.77 per cent in 1901, 15.74 per cent in 1902, and 15 per cent in 1903. This is only one of many examples.

8 The protein content was highest in 1900 and 1902, years when the rainfall was somewhat deficient during the ripening period. This gave a short, quick ripening period, retarding the elaboration and transference of the starch from the stems to the grains and so increasing the protein content. The climatic peculiarity noted accounts largely for the high protein content of Tennessee wheat.

9 A rich soil or the use of large quantities of commercial fertilizer or farmyard manure does not seem to increase the protein content of wheat to an appreciable extent.

10 The per cent of flour produced by Tennessee wheat is high, the leading varieties being equal or superior to those most commonly grown and highly esteemed in other sections. Fulcaster ranged from 70 to 75 per cent and averaged 73.4 per cent.

11 In color some of the hardest varieties are not quite equal to some of the white, soft wheats produced in other sections, but the hard varieties produced in Tennessee are equal in merit to those produced in other sections. As the hard varieties produce much more gluten, and are better adapted to Tennessee conditions, and are preferred by the millers, farmers would do well to cultivate them more extensively; for the flour can be materially improved in color by being properly baked.

12 The number of loaves per barrel obtained from Tennessee flours equals or exceeds the number obtained from wheat grown in other sections.

13 The loaf obtained from Tennessee flour is apparently not quite so large as that obtained from the flour of Minnesota spring wheat, but the difference is slight.

14 The difference in quality of gluten is not so important as might be thought at first because the yield of the hard wheat is much greater and the gluten content of the flour from hard wheat is higher than from soft wheat. This explains why the millers prefer Fulcaster and Mediterranean and why these varieties are more desirable for general culture in the State than soft, white wheat.

15 The statements presented in this bulletin show emphatically that Tennessee produces a superior quality of wheat for milling and bread making purposes; that climatic and soil conditions adapt the State admirably for wheat production; that cereal growing should be a leading agricultural industry; and that statements to the effect that Tennessee is not a good wheat producing state when the soil is rationally treated are not well founded.

16 To maintain and improve the "standard" of a variety the seed must be carefully graded and selections made from the best type heads in the field. Large increases will not be obtained by this method, but the variety can be maintained indefinitely and adapted to local conditions.

17 A large increase in yield will not be obtained immediately by the selection from type heads, and the work should not be undertaken unless it can be systematically carried on through a series of years.

18 Fertilizers give their best results on a soil well supplied with vegetable matter. It is easy to use fertilizers at a loss with wheat unless the character of the soil is well understood.

19 Many impoverished soils can be made profitable for wheat production by the plowing under of cowpeas and the liberal application of phosphates, potash and lime. Soils tilled for many years are often acid, and lime corrects this fault.

20 Farmyard manure applied at the rate of 15 tons to the acre increased the yield of wheat on bare fallow 10.71 bushels in 1902. Fertilizers alone on a poor soil failed to increase the yield more than from three to five bushels, and in a dry season they were used at a loss. When cowpeas were plowed down the increase varied from five to eleven bushels in a favorable season and from three to eight in a dry season. Cowpea when sown as a "catch crop" can be counted on to increase the yield of wheat several bushels per acre.